MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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H. F. NEWALL, Esq., M.A., F.R.S., PRESIDENT, in the Chair.

Major-General Henry Herbert Lee (late R.E.), The Mount, Dinas Powis, near Cardiff, South Wales;
Augustus Edward Hough Love, D.Sc., F.R.S., Sedleian Professor of Natural Philosophy, Oxford;
Rev. Reginald William Bickerton Moore, M.A., Vicar of St James's, Bath, 11 Devonshire Buildings, Bath; and
Herbert Gerard Tomkins, Government of India Finance Department, 86 Old Dover Road, Canterbury,

were balloted for and duly elected Fellows of the Society.

Anders Donner, Director of the Observatory, Helsingfors, Finland, was balloted for and duly elected an Associate of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Burdett Mason, Larondouette, Bayonne, France (proposed by W. E. Wilson); and
Arthur William Meers, F.R.G.S., Merchant, Lugano, Wickham Park, Beckenham, Kent (proposed by S. A. Saunder).

Ninety-three presents were announced as having been received since the last meeting, including, amongst others:—

The Oxford Astrographic Catalogue, vol. 2, presented by the

University Observatory, Oxford; Potsdam Observatory, Photographische Himmelskarte, Band 4, presented by the Observatory; Dr Backlund's Reports on the Russian Mission for the measurement of an Arc of Meridian in Spitzbergen, presented by the Pulkowa Observatory.

Twenty charts of the Astrographic Chart of the heavens, presented by the Royal Observatory, Greenwich; six positive enlargements on glass of photographs of portions of the Solar Surface, taken at the Royal Observatory, Greenwich, and photograph of the Solar Eclipse of 1905 August, taken at Sfax, Tunis, presented by the Astronomer Royal; nine photographs of Mount Wilson Observatory, and photographs of the Spectra of Sun-spots, presented by Prof. G. E. Hale.

On the Inclinations of Binary Star Orbits to the Galaxy.

By T. Lewis and H. H. Turner.

Summary.

§ 1. It was suggested that the axes of rotation of variable stars tend to be parallel to the Galaxy. Do double stars tend to revolve in corresponding fashion?

§ 2. List of 59 orbits.

§§ 3–5. Application of method used for variables: with the result that orbits nearly at right angles to the line of sight seem to avoid the Galactic Poles, as was noticed for stars which present their poles to us.

§§ 6–12. Discussion of distribution of the spurious poles of double-star orbits, and conclusion that at least 75 per cent. are scattered uniformly over the sphere.

§ 13. If they were uniformly scattered there would remain $38\frac{1}{2}$ real poles within 30° of the Galaxy and $20\frac{1}{2}$ in the rest of the sphere: whereas, on the hypothesis of uniform distribution, both numbers should be $29\frac{1}{2}$.

§ 14. If the small orbits ($a<0''{\cdot}5$) be excluded, there are 33 poles within 30° of the Galaxy as against 15 in the remainder of the sphere.

§§ 15–16. There is evidence of systematic error in very small distances, which would specially affect small orbits.

§ 17. If orbits of large eccentricity be excluded ($e>0{\cdot}51$) there remain 21 poles within 30° of the Galaxy, and 5 in the rest of the sphere.

§§ 18 and 19. Remarks on high eccentricities.

1. In a paper by one of the present writers on the "Classification of Long-period Variables" (*Mon. Not.*, lxvii. p. 332), it was suggested that the type of light curve might indicate the inclination of the axis of rotation of the star to the line of sight; and attention was drawn to the fact that, in terms of this hypothesis, there were no variables near the poles of the Milky Way with their axes turned towards us. After the meeting at which the above paper was read, Mr Inwards suggested that the orbits of double stars might show a similar peculiarity of distribution. Various attempts have already been made to detect any such peculiarity, without success; see, for example, pp. 244–6 of Dr T. J. J. See's *Evolution of Stellar Systems*, and Miss Everett's paper in *Mon. Not.*, lvi. pp. 464–5. On examining these lists, it will be seen that there is no very well-marked feature of distribution; but at the same time there appear to be certain tendencies which have perhaps not yet received sufficient attention, and the following notes may serve to promote further inquiry.

2. There were some discrepancies in the two lists above mentioned; and other orbits have since been computed. Hence the first step was to form a revised list of orbits as follows:—

TABLE I.

List of 59 Orbits in Order of R.A. of Star.

No.	Name.	R.A.	Dec.	Gal. Lat.	e	a	i	Γ	Γ
		h. m.	°	°		"	°	°	°
1	Σ 3062	0 1	+58	− 4	0·45	1·37	44	64	51
2	Σ 2	0 4	+79	+16	·40	0·55	70	84	81
3	13 Ceti	0 30	− 4	−67	·74	0·21	48	69	30
4	β 395	0 32	−25	−87	·15	0·66	77	78	56
5	η Cassiop.	0 43	+57	− 6	·34	8·51	43	67	54
6	36 Androm.	0 50	+23	−40	·75	1·01	45	87	10
7	Σ 186	1 51	+ 1	−57	·67	1·15	74	84	78
8	γ^2 Androm.	1 58	+42	−19	·82	0·35	77	83	33
9	Σ 228	2 8	+47	−13	·38	0·90	66	66	49
10	20 Persei	2 48	+39	−19	·48	0·24	74	38	14
11	40 Eridani	4 11	− 8	−37	·14	6·25	69	60	18
12	β 883	4 46	+11	−20	·48	0·24	28	79	66
13	Sirius	6 40	−17	− 8	·59	7·59	45	78	66
14	9 Argus	7 41	−14	+ 8	·70	0·65	78	57	53
15	ζ Cancri	8 6	+18	+26	·38	0·86	11	67	62
16	ε Hydræ	8 41	+ 7	+38	·68	0·24	36	89	41
17	Σ 3121	9 12	+29	+44	·33	0·67	75	67	62

TABLE I.—*continued.*

No.	Name.	R.A. h. m.	Dec. °	Gal. Lat. °	e	a "	i °	Γ °	Γ' °
18	ω Leonis	9 23	+ 9	+40	·54	0·88	63	67	14
19	ϕ Ursæ Maj.	9 45	+55	+48	·44	0·34	30	64	26
20	ξ Ursæ Maj.	11 13	+31	+70	·40	2·51	56	59	57
21	ι Leonis	11 19	+11	+64	·76	2·49	66	71	65
22	0Σ 234	11 25	+42	+68	·30	0·35	51	65	42
23	0Σ 235	11 27	+62	+53	·32	0·87	49	89	19
24	Σ 1639	12 20	+26	+86	·70	0·71	58	61	55
25	γ Centauri	12 36	−48	+14	·80	1·02	62	86	81
26	γ Virginis	12 37	− 1	+62	·88	3·90	30	43	36
27	42 Comæ	13 5	+18	+82	·48	0·66	90	83	83
28	0Σ 269	13 28	+36	+77	·36	0·32	71	69	61
29	25 Can. Ven.	13 33	+37	+75	·87	1·12	36	43	26
30	β 612	13 35	+11	+70	·27	0·31	64	83	46
31	α Centauri	14 32	−60	− 1	·53	17·70	79	88	43
32	Σ 1879	14 41	+10	+57	·65	0·84	64	87	36
33	ξ Boötis	14 47	+20	+61	·59	5·33	51	81	35
34	η Cor. Bor.	15 19	+31	+56	·27	0·92	52	88	30
35	μ^2 Boötis	15 21	+38	+54	·54	1·27	44	77	11
36	0Σ 298	15 32	+40	+51	·58	0·80	61	83	25
37	γ Cor. Bor.	15 39	+27	+50	·42	0·73	84	79	67
38	ξ Scorpii	15 59	−11	+29	·77	0·70	72	77	50
39	σ Cor. Bor.	16 11	+34	+45	·54	3·82	47	90	18
40	λ Ophiuchi	16 26	+ 2	+30	·68	0·99	30	61	46
41	ζ Herculis	16 38	+32	+39	·56	1·40	50	85	24
42	De 15	16 41	+44	+40	·36	0·77	75	81	44
43	Σ 2107	16 48	+29	+38	·48	0·73	14	67	38
44	β 416	17 12	−35	+ 1	·51	1·22	37	86	72
45	Σ 2173	17 25	− 1	+17	·20	1·14	81	61	54
46	μ^1 Herculis	17 43	+28	+25	·22	1·39	64	83	48
47	τ Ophiuchi	17 58	− 8	+ 7	·59	1·25	58	72	50
48	70 Ophiuchi	18 0	+ 3	+10	·50	4·55	58	88	81
49	99 Herculis	18 3	+31	+21	·78	1·01	0	68	68
50	ζ Sagittarii	18 56	−30	−16	·28	0·69	67	60	45

TABLE I.—*continued.*

No.	Name.	R.A.	Dec.	Gal. Lat.	*e*	*a*	*i*	Γ	Γ′
		h. m.	°	°		″	°	°	°
51	γ Cor. Austr.	19 0	−37	−19	·42	2·45	34	87	53
52	Σ 2525	19 23	+27	+ 4	·95	1·41	57	38	28
53	0Σ 400	20 7	+47	+10	·40	0·57	69	83	73
54	β Delphini	20 33	+14	−17	·37	0·67	61	54	31
55	4 Aquarii	20 46	− 6	−30	·51	0·73	73	61	30
56	δ Equulei	21 10	+10	−27	·36	0·31	77	42	21
57	τ Cygni	21 11	+38	− 8	·37	1·16	47	75	63
58	κ Pegasi	21 40	+25	−22	·49	0·42	81	74	68
59	85 Pegasi	23 57	+27	−35	·39	0·89	56	80	66

3. In the last two columns of the above table, under the notation Γ and Γ′ adopted by Dr See, are given the two possible inclinations of the orbital planes to the plane of the Galaxy. This ambiguity has hitherto somewhat embarrassed the discussion of the distribution of the inclinations in space, and we shall presently return to the consideration of it. But first it may be remarked that it need not trouble us if we adopt the method used in the case of variable stars: for we are at least as well off in dealing with double-star orbits as in dealing with variable stars. We know the inclination of the plane to the line of sight, though we do not know on which side it lies. In the case of the variables, we similarly suppose that we have indications of the inclination of the equator (or of the axis of rotation) to the line of sight, but as regards its orientation round the line of sight we are quite ignorant—our alternatives are infinite in number instead of being two only. Hence we can at any rate apply to the double-star orbits the same test as to the variables; and we proceed to do this in the first instance.

4. On p. 351 of the present volume of *Mon. Not.* is given a list of twenty stars with large values of a, the suggestion being that these are rotating suns which present their polar regions to us, their equators lying at right angles to the line of sight. The analogy in the case of a double star is an orbit for which i is small, so that the apparent orbit is well open. The values of i are given in the 8th column of the above table, and we can accordingly pick out the small values of i; or, what is more complete, arrange the whole series according to the value of i as in Table II.

TABLE II.

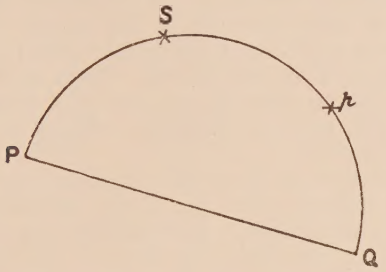
Orbits in Order of Inclination to Plane of Projection.

i	Star's No	Gal. Lat.	i	Star's No.	Gal. Lat.	i	Star's No.	Gal. Lat.
°		°	°		°	°		°
0	49	+21	50	41	+39	69	53	+10
11	15	+26	51	22	+68	69	11	−37
14	43	+38	51	33	+61	71	28	+77
28	12	−20	52	34	+56	72	2	+16
30	40	+30	56	59	−35	72	38	+29
30	19	+48	56	20	+70	73	55	−30
33	26	+62	57	52	+ 4	74	10	−19
34	51	−19	58	47	+ 7	74	7	−57
36	16	+38	58	24	+86	75	17	+44
36	29	+75	58	48	+10	75	42	+40
37	44	+ 1	61	36	+53	77	4	−87
43	5	− 6	61	54	−17	77	8	−19
44	1	− 4	62	25	+14	77	56	−27
44	35	+54	63	18	+40	78	14	+ 8
45	6	−40	64	30	+70	79	31	− 1
45	13	− 8	64	32	+57	81	45	+17
47	39	+45	64	46	+25	81	58	−22
47	57	− 8	66	9	−13	84	37	+50
48	3	−67	66	21	+64	90	27	+82
49	23	+53	67	50	−16			

5. It will be seen from Table II. that the orbits with small values of i do show some tendency to lie near the Galaxy. There are exceptions such as No. 29 which, with an inclination of 36°, has a Galactic Latitude of 75°. This star is 25 Canum Ven. It has not yet completed a revolution (period 220 years) or been observed near apastron, while the orbit is so eccentric that it cannot be observed near periastron; consequently the elements are somewhat uncertain: possibly further knowledge will sensibly increase the value of i and the eccentricity, which seem (from inspection of the three orbits computed) to go together. But to enter upon criticism of orbits computed would take us too far: it is sufficient to remark here that there may be considerable uncertainty in the determination of i, as a few examples will illustrate. Thus in the case of γ Virginis (No. 26) there will be found on p. 339 of *Mem. R.A.S.*, vol. lvi., a list of 22 orbits with values of i ranging from 0° to 68°. They are not all of equal merit, but all of them are *bonâ fide* attempts to satisfy the observations. Again, for λ Ophiuchi the value 58° rather than 30° has been assigned to i; for ξ Scorpii the value of i has recently been changed from 72° to 29°; for ξ Boötis

the values range from 35° to 80°, and so on. Of course this uncertainty cuts both ways, and cannot be used to bring the above table into better accord with a hypothesis; but it is to be remembered as a possible explanation of discrepancies.

6. Before proceeding to analyse the columns Γ and Γ′, it is desirable to consider the general effect of the ambiguity. Let us represent each orbit by its pole, *i.e.* the point in which a line perpendicular to it cuts the celestial sphere. For every real pole P there is a corresponding spurious pole p on the opposite side of the



star S, and equidistant from it. We cannot tell without independent evidence such as may ultimately be afforded by the spectroscope,* which is the right one. But we can study this question:—Suppose P tends to lie near the Milky Way for all positions of S, will p have a tendency to lie in any particular region or regions? and, if so, which?

7. A preliminary question must first be asked with regard to the distribution of the star S. Does it appear from the above list that double stars congregate towards the Milky Way? The numbers for every 10° of Galactic Latitude are as follows:—

Table III.

Distribution of the Stars of Table I. in Galactic Latitude.

Galactic Lat.	Observed No. of Stars.	Calcd.	O−C.
0° − 9°	9	10	−1
10 − 19	13	10	+3
20 − 29	6	9	−3
30 − 39	7	9	−2
40 − 49	6	7	−1
50 − 59	7	6	+1
60 − 69	4	4	0
70 − 90	7	4	+3
Total	59	59	0

* It is strange to think that we do not yet know which is the real orbit even of α Centauri. Could not some spectroscopic observer determine this for us? There are also η Cassiopeiæ, p Eridani, and others.

In the column "Calc." the theoretical distribution of 59 stars, uniformly scattered over the sphere, is given. The column O − C shows that the actual stars are in defect near the Galaxy and in excess near its poles. But the differences are small and the scattering may be taken as nearly uniform.

8. Returning now to the figure, let us suppose in the first instance that, the pole P being given and remaining therefore fixed, the star S is scattered at random over the sphere. What will be the consequent distribution of the spurious pole p? One feature of it is especially noteworthy. The most common value of PS will be 90°, since the equator of P is the largest circle with centre P. Now all the stars which lie in the equator of P have corresponding poles at 180° from P (since $Pp = 2PS$): that is, in Q, the point opposite to P on the sphere. There is thus a great concentration of spurious poles in and near this point Q. Similarly the point Q will, as a real pole, give rise to a concentration of spurious poles near P.

9. It is easy to write down the symbolical expressions for the density of the spurious poles, but it will be more directly useful to us to work with numbers. Starting with the numbers of stars in each zone of 10° outwards from P up to PS = 90°, the spurious poles of these will fall in zones of 20°, up to $Pp = 180°$. The stars in the hemisphere for which PS > 90° will be referred to pole Q, and will give a series of numbers in the reverse order; and adding together the two, we get a distribution of spurious poles (corresponding to a uniform scattering of stars and a given pair of real poles PQ) as follows:—

TABLE IV.

PS.	Number of Stars: see Table III.	Pp.	Number of Spurious Poles.	Uniform Dist.	Excess over Uniformity.
° °		° °			
0–10	1	0– 20	1 + 10 = 11	3	+ 8
10–20	3	20– 40	3 + 10 = 13	8	+ 5
20–30	4	40– 60	4 + 9 = 13	12	+ 1
30–40	6	60– 80	6 + 9 = 15	14	+ 1
40–50	7	80–100	7 + 7 = 14	15	− 1
50–60	9	100–120	9 + 6 = 15	14	+ 1
60–70	9	120–140	9 + 4 = 13	12	+ 1
70–80	10	140–160	10 + 3 = 13	8	+ 5
80–90	10	160–180	10 + 1 = 11	3	+ 8
Total			118	89	29

10. Thus for uniformly scattered stars we have, out of 118 spurious poles, 89 of them scattered uniformly over the sphere and 29 tending to collect round the real poles, the density near the poles being quite considerable.

11. If then the 59 real poles lie near the Milky Way, while the stars are scattered uniformly over the sphere, we shall have

44 of the spurious poles scattered uniformly over the sphere and 15 tending to coincide with the real poles near the Milky Way.

Now we may proceed in the following manner. We may assume in the first instance that the spurious poles are all uniformly scattered, and then deduce the distribution of the real poles. If any peculiarity of distribution is found, we must then reduce it by some 20 per cent. to allow for the spurious poles.

13. Let us therefore consider the distribution of real and spurious poles together, and then make allowance for the spurious poles on the principle of uniform scattering; this is done in Table V.

Table V.

Values of Γ or Γ'.	Observed Total Number.	Subtract Uniform Distribution of Γ'.	Γ alone.	Observed Excess over Unif. Distr.
$0^\circ - 19^\circ$	7	4	3	− 1
20 – 29	6	4	2	− 2
30 – 39	11	6	5	− 1
40 – 49	12	7	5	− 2
50 – 59	14	$8\frac{1}{2}$	$5\frac{1}{2}$	− 3
60 – 69	28	$9\frac{1}{2}$	$18\frac{1}{2}$	+ 9
70 – 79	13	10	3	− 7
80 – 90	27	10	17	+ 7
Total	118	59	59	0

In the second column are given the number of cases (from Table I.) where either Γ or Γ' lies within the limits indicated in the first column. In the third, an allowance is made for Γ' on the hypothesis of uniform distribution. The remaining numbers in the fourth column should represent the distribution of the real poles: and in the fifth column this is compared with a random or uniform distribution. It will be seen that an excess towards the Galaxy exists, though it is not very large. Still it is large enough to make it impossible, for instance, to maintain the contrary proposition—that the orbits of double stars tend to lie parallel to the Galaxy.

14. The above result is obtained from the whole list of orbits, without any selection. But it is noteworthy that if we limit the inquiry to the larger orbits, the tendency of the poles toward the Galaxy is more marked. It seems worth while to put on record the result, for example, of limiting the material to orbits of which the semi-major axis exceeds $0''{\cdot}50$. Recurring to Table I., there are 48 of these orbits: and for them we should replace Table V. by Table VI. as follows:—

TABLE VI.

Larger Orbits only.

Values of Γ or Γ′.	Observed Total Number.	Subtract Uniform Distribution of Γ′.	Γ alone.	Observed Excess over Unif. Distr.
° ° 0 – 19	6	3	3	0
20 – 29	4	3	1	−2
30 – 39	8	5	3	−2
40 – 49	8	6	2	−4
50 – 59	13	7	6	−1
60 – 69	22	8	14	+6
70 – 79	11	8	3	−5
80 – 90	24	8	16	+8
Total	96	48	48	0

15. The exclusion of the smaller orbits is reasonable since there is systematic error affecting observations of very close doubles. The following figures will illustrate the nature of this error. In Dr T. J. J. See's *Evolution of Stellar Systems*, tables are given showing the residuals $(\rho_o - \rho_c)$ of the observed distances over the calculated. These were collected according to the value of ρ_c in all cases where ρ_c falls below 0″·60 after the year 1870. [The measurement of very small distances has become more feasible in recent years, and it was thought better to limit the inquiry to modern observations.] The following table gives the results for all orbits represented in all three of the groups selected :—

TABLE VII.

Evolution of Stellar Systems. $\rho_o - \rho_c$ *for small values of* ρ_c.

Star.	ρ_c = 0″·60 to 0″·45.		0″·44 to 0″·25.		Under 0″·25.	
	$\rho_o - \rho_c$. (Sum).	No. Obs.	$\rho_o - \rho_c$. (Sum).	No. Obs.	$\rho_o - \rho_c$. (Sum).	No. Obs.
γ Androm.	+ ″·02	6	+ ″·10	4	+ ″·14	7
9 Argus	− ·01	3	+ ·03	7	+ ·06	1
Σ 3121	− ·20	7	+ ·21	11	+ ·08	4
42 Com. Ber.	+ ·21	8	+ ·25	8	− ·02	3
OΣ 298	+ ·09	3	− ·11	10	+ ·14	2
γ Cor. Bor.	− ·63	6	− ·11	3	+ ·60	2
Σ 2173	− ·07	3	− ·10	4	+ ·01	2
β Delphini	− ·10	4	− ·04	9	+ ·21	4
δ Equulei	− ·57	4	− ·20	6	+ ·10	3
Sums	− ″1·26	44	+ ″·03	62	+ ″1·32	28
Means	− ″0·029	...	+ ″0·000	...	+ ″0·047	...

16. It thus appears that double-star observers are liable to measure very small distances too large. There is nothing unreasonable or even unlikely in this, and the above figures may even underestimate the amount, since some concession to the error is probably made in determining the orbit. Now, if the existence of such an error is admitted, the elements of the small orbits will require systematic revision. It is not easy to say what the general effect on the inclinations would be, and such an inquiry cannot in any case be undertaken here. But it seems desirable to suspend judgment at present, with regard to any distribution of orbital inclinations, until we know more of the possible systematic errors of the smaller orbits.

17. If, now, we further limit the material to orbits of moderate eccentricity, the figures become still more striking. Excluding from the 48 above, 22 orbits for which e exceeds 0·51, we get—

TABLE VIII.

Values of Γ or Γ′.	Observed Total Number.	Subtract for Γ′.	Γ alone.	Excess over Uniform.
° ° 0 – 19	2	2	0	−2
20 – 29	0	2	(−2)	−4
30 – 39	4	2	2	0
40 – 49	4	3	1	−2
50 – 59	8	4	4	0
60 – 69	15	4	11	+7
70 – 79	5	4	1	−3
80 – 90	14	5	9	+4
Total	52	26	26	0

18. The limit $e = 0{\cdot}51$ was selected in order to make the excess near the Galaxy as striking as possible. The general effect of including other orbits can be seen from the following figures for the 48 orbits:—

Value of e . . .	< ·40	·40 to ·51	·52 to ·59	·60 to ·79	> ·80	Total
Values of Γ and Γ′ < 60°	12	6	8	7	6	39
,, > 60°	18	16	10	11	2	57

or if we assume uniform distribution of Γ′ the numbers would be

Value of e . .	< ·40	·40 to ·51	·52 to ·59	·60 to ·79	·80 and over
Values of Γ < 60°	4½	½	3½	2½	4
,, Γ > 60°	10½	10½	5½	6½	0

The difference between the results for large values of e and those for small may be due either to observational or to physical causes. When the stars approach very close together, observations are difficult and likely to be affected by systematic error, so that the determinations of inclination will be affected; and on the

other hand, just as in the solar system the planetary orbits are at the same time of small eccentricity and systematically disposed near one plane (which is at a high inclination to the Galaxy), while comets have orbits of high eccentricity with planes in miscellaneous orientations,—so there may be a real difference between double star orbits of low and of high eccentricity.

19. It seems worth while to form a new table corresponding to Table II. for the 26 orbits retained in Table VIII.

TABLE IX.

Similar to Table II., but excluding orbits of small size ($a<0''\cdot5$) and high eccentricity ($e>0\cdot51$).

i	Star's No.	Gal. Lat.	i	Star's No.	Gal. Lat.	i	Star's No.	Gal. Lat.
11	15	+26°	56	20	+70°	75	17	+44°
14	43	+38	58	48	+10	75	42	+40
34	51	−19	61	54	−17	77	4	−87
37	44	+ 1	64	46	+25	81	45	+17
43	5	− 6	66	9	−13	84	37	+50
44	1	− 4	67	50	−16	90	27	+82
47	57	− 8	69	53	+10			
49	23	+53	69	11	−37			
52	34	+56	72	2	+16			
56	59	−35	73	55	−30			

Ancient Eclipses. By P. H. Cowell, F.R.S.

As my whole argument from the ancient lunar eclipses is—"If I have placed a wrong interpretation upon the records of solar eclipses, how is it that the results so obtained agree so well with the lunar eclipses?" I am, of course, perfectly satisfied with such sentences as these in Mr Nevill's recent papers:—

"During past years in my researches I have repeatedly found evidence of an unexplained apparent secular acceleration in the motion of the Moon's argument of latitude . . . ." (*M.N.*, lxvii. p. 17).

"These early eclipse observations . . . . are certainly not inconsistent with Mr Cowell's conclusion that the Moon's argument of latitude requires an increased secular acceleration" (p. 13).

In my view the lunar eclipses by themselves do not amount to a proof, and I do not ask Mr Nevill to say more than he has said.

Mr Nevill, however, attaches more weight than I do to the times of lunar eclipses. From the times the mean elongation is

deduced, whereas the argument of latitude is found from the magnitudes. For the mean elongation, Mr Nevill deduces a secular term 7″·4 from the Ptolemaic eclipses and 6″·2 from the Arabian eclipses. I regard the agreement of these numbers with the 6″·8 that I obtained from solar eclipses as most satisfactory. Mr Nevill (p. 10) regards 6″·8 as inconsistent with both 6″·2 and 7″·4. Apparently, upon the inconsistency of 6″·2 with 7″·4, he bases his supposition of unknown long-period terms. But he has not shown that the 6″·2 and 7″·4 are subject to such small probable errors as to negative the possibility that the discordance is accidental. My view, of course, is that 6″·8 is nearly the true value.

It is on the solar eclipses that I rely. The divergence between Mr Nevill's views and my own in this case arises largely from differences of numerical calculation, and the first thing to be done is to remove those differences. The following table gives for several solar eclipses (1) my residual, which is approximately the least distance between the centres of the Sun and Moon as seen from the place assumed in the calculations; (2) the quantity which Mr Nevill calls "Cowell's $d\phi$."

Date.	Residual. See *M.N.*, lxvi. 531.	$d\phi$ See *M.N.*, lxvi. 414, 416.
− 309	−177″	−0°·9
− 399	+ 14	+3·1
− 403	−525	−2·4
− 430	+ 34	+0·1
− 602	+ 46	−0·6
− 647	+ 8*	+0·5
− 660	+163	+6·0
− 678	+115	+4·8
− 762	− 42	−0·8
−1062	+ 29	+0·8
−1123	−697	−2·1
− 600	+429	+2·0
− 708	+211	−3·0
− 180	+ 27	+0·9
− 187	+456	+1·9
− 299	−157	−3·3

The relationship between my residual and Mr Nevill's $d\phi$ is a complicated one; the following test will, however, serve to detect large errors:—"Divide $d\phi$ by 60 and compare with the residual, allowing 100″, partly because the divisor 60 is only approximate

* From *M.N.*, lxv. p. 867.

and partly on account of approximations used in obtaining the residual, and possibly other approximations used in obtaining $d\phi$."

It will be noted that this is a very rough test. My point is that certain formulæ will give residuals of less than 50″ for several eclipses, and in applying the above test I allow 100″; hence discrepancies in arithmetic that are important for my argument may slip through, undiscovered by the test, which only detects the still larger discrepancies.

The test, however, brings to light discrepancies in the eclipses of −309, −399, −403, −660, −678, −1123, −600, −708, −187. To this list −1116 would also have been added if Mr Nevill (*M.N.*, lxvii. p. 15) had not corrected his result as given on *M.N.*, lxvi. p. 414.

Assuming for the moment that my figures are correct, it is evident that Mr Nevill has not appreciated the superior precision of solar eclipses. Lunar eclipses are liable to errors of a tenth of a magnitude or 200″, but solar eclipses appear to be only liable to uncertainties of 50″, a little greater than the maximum difference of semidiameter.

If, on the other hand, Mr Nevill's figures are correct, solar eclipses exhibit residuals as large as lunar eclipses, and the case for an unexplained acceleration in the Moon's argument of latitude ceases to amount to anything like certainty.

Now it would be only natural that Mr Nevill and I should each of us believe that the discrepancies exhibited above are due to the blunders in computation of the other. What I now ask of Mr Nevill is that he should put me into the same position with regard to his computations as that into which I have already put him with regard to mine. I have set down every formula that I have used. In my papers on the eclipses of +1030, +1239, and +1241, it can be seen to what extent the formulæ used for ancient eclipses are approximate. On *M.N.*, lxvi. pp. 533–536, a full calculation is given for one eclipse. In all cases numerical results for a great number of intermediate stages are given.

But, in Mr Nevill's computations, I do not know whether he has calculated his own places for the Sun and Moon, or used Oppolzer's, with suitable modifications. In either case I do not know what inequalities he has retained. Further, I should like to see the numerical places obtained in the various cases, so that I can tell whether the discrepancies between our results arise in the geocentric places or parallactic part of the calculations. Again, on *M.N.*, lxvii. p. 15, Mr Nevill says: "The changed path of the curve of central totality can be deduced from the comparison of the new positions of the beginning, middle, and the end of eclipse with those given by Oppolzer." What path of the curve of central totality underlies the changes deduced by Mr Nevill? The paths published by Oppolzer are not sufficiently accurate, but Mr Nevill has not stated by what formulæ he has calculated his own paths. All the information for which I ask could be supplied if Mr Nevill, in addition to some intermediate results for all eclipses, would

publish at full length and with suitable explanations the entire calculation for one eclipse. If he will do this, I should be glad if he will select the eclipse of -1123. This is a very important one, for his figures on *M.N.*, lxvi. p. 414, indicate that the theoretical accelerations (Mr Nevill's B) make this eclipse total near Babylon. My figures on *M.N.*, lxvi. p. 532, contradict this conclusion.

As the foregoing remarks have brought me to the eclipse of Babylon, I may add—

1. Mr King originally indicated the second half of the eleventh century B.C. as the probable date. He has recently discussed this eclipse very fully in the first volume of *Chronicles concerning Early Babylonian Kings* (Luzac & Co., 1907).

2. According to my calculations, at no date in the summer months of either the eleventh or twelfth centuries B.C. except -1062 July 31 could the Babylonians have seen any phenomenon answering to the words of the inscription quoted on *M.N.*, lxv. p. 861.

3. Mr King, though he dislikes the equation, Sivan $26 =$ July 31, does not reject it. I see no alternative to accepting it.

The Perturbations of Halley's Comet. By P. H. Cowell and A. C. D. Crommelin.

The action of Saturn is here considered. The calculations are similar in character to those for the action of Jupiter published on pp. 386–411.

The differential equations given on p. 386 are again applicable. In the value of e_x on that page the square root should be omitted, so that we have

$$e_x = -(1 - e^2) \sin u \cos u.$$

Table I., pp. 387–390, is again applicable. The tabulated values of e_x are correct.

The $V = V_3 + V_4$ method explained on p. 391 is again introduced at $u = 90°$ and dropped at $u = 270°$. V_4 would be the disturbing function if the motion were referred to the centre of gravity of the Sun and disturbing planet. Hence $V_3 = V - V_4$ is the change in the disturbing function that would arise from a displacement of the origin of co-ordinates. This consideration gave us the assurance, *a priori*, that the differential equations depending on V_3 would be integrable.

The positions of Saturn have been taken from a table with argument g' mean anomaly of Saturn similar to Table II., pp. 394–401. The table is not printed here, but it is based upon the following assumptions and formulæ.

For Saturn $e' = \cdot 05607$, hence

$$\frac{\xi'}{a'} = -\frac{3}{2}e' + \left(1 - \frac{3}{8}e'^2\right)\cos g' + \left(\frac{1}{2}e' - \frac{1}{3}e'^3\right)\cos 2g' + \frac{3}{8}e'^2\cos 3g' + \frac{1}{3}e'^3\cos 4g'$$

$$= \cos g' - \cdot 084\ 105 - \cdot 001\ 179\cos g' + \cdot 027\ 976\cos 2g' + \cdot 001\ 179\cos 3g' + \cdot 000\ 059\cos 4g'$$

$$\frac{\eta'}{a'} = \left(1 - \frac{5}{8}e'^2\right)\sin g' + \left(\frac{1}{2}e' - \frac{5}{12}e'^3\right)\sin 2g' + \frac{3}{8}e'^2\sin 3g' + \frac{1}{3}e'^3\sin 4g'$$

$$= \sin g' - \cdot 001\ 965\sin g' + \cdot 027\ 962\sin 2g' + \cdot 001\ 179\sin 3g' + \cdot 000\ 059\sin 4g'$$

Also

$$g' = 112^\circ \cdot 09 + 144^\circ \cdot 8437\ nt$$

$$\frac{a'}{a} = \cdot 539\ 842$$

Also let NCϖ be the comet's orbit, YCS the ecliptic of 1850, Nϖ'S the orbit of Saturn,

$$\Upsilon C = 55^\circ\ 50' \quad C\varpi = 111^\circ\ 0' \quad NCS = 17^\circ\ 46'$$
$$\Upsilon S = 112^\circ\ 21' \quad S\varpi' = -22^\circ\ 14' \quad CSN = 2^\circ\ 30'$$

Hence $NC = 6^\circ\ 20' \quad N\varpi = 117^\circ\ 20'$
$NS = 50^\circ\ 31' \quad N\varpi' = 28^\circ\ 17'$
$CNS = 180^\circ - 19^\circ\ 15'$,

and hence

$$\frac{x'}{a} = -\cdot 432\ 815\frac{\xi'}{a'} - \cdot 281\ 251\frac{\eta'}{a'}$$

$$\frac{y'}{a} = -\cdot 311\ 431\frac{\xi'}{a'} + \cdot 433\ 315\frac{\eta'}{a'}$$

$$\frac{z'}{a} = +\cdot 084\ 333\frac{\xi'}{a'} + \cdot 156\ 733\frac{\eta'}{a'}$$

We have performed the mechanical quadratures with intervals $du = 2^\circ$. With this value of du

$$\left(\frac{a}{r'}\right)^3 du = \cdot 222\ 920 + \cdot 037\ 453\cos g' + \cdot 003\ 139\cos 2g' + \cdot 000\ 259\cos 3g'$$

Table III. (the enumeration being the same as on pp. 402–404) gives the disturbing forces.

TABLE III.

First Quadrant. Unit 0·0001.					*Second Quadrant.* Unit 0·0001.				
u	g'	$a^2X\,du$	$a^2Y\,du$	$a^2Z\,du$	u	g'	$a^2X_4\,du$	$a^2Y_4\,du$	$a^2Z_4\,du$
°	°				°	°			
1	112·17	− 68	− 6	+ 1	91	202·07	+ 104	− 94	+ 33
3	112·34	74	+ 31	11	93	207·29	105	77	31
5	112·52	76	70	22	95	212·69	104	62	30
7	112·71	76	111	34	97	218·26	100	47	29
9	112·93	71	157	47	99	223·99	95	34	27
11	113·17	62	205	61	101	229·90	88	23	25
13	113·44	48	255	75	103	235·97	80	12	23
15	113·75	− 28	308	90	105	242·21	72	− 3	21
17	114·11	+ 2	360	106	107	248·61	61	+ 5	19
19	114·51	38	414	120	109	255·18	52	11	17
21	114·97	86	466	135	111	261·91	41	16	15
23	115·50	142	512	149	113	268·80	30	21	13
25	116·08	209	548	160	115	275·84	19	22	10
27	116·75	286	574	168	117	283·04	10	23	8
29	117·48	369	579	172	119	290·39	+ 1	21	6
31	118·30	457	566	171	121	297·89	− 7	20	4
33	119·21	545	531	165	123	305·54	13	16	2
35	120·22	625	470	153	125	313·33	18	11	+ 1
37	121·32	694	384	136	127	321·26	21	+ 6	0
39	122·52	743	279	114	129	329·33	21	1	0
41	123·83	770	156	91	131	337·53	18	9	0
43	125·25	772	+ 25	67	133	345·86	12	15	+ 1
45	126·79	751	− 107	43	135	354·31	− 3	20	3
47	128·45	709	236	22	137	2·88	+ 8	23	6
49	130·23	648	356	+ 4	139	11·57	19	22	10
51	132·15	572	461	− 10	141	20·37	28	17	12
53	134·19	488	553	19	143	29·28	32	10	14
55	136·37	398	629	24	145	38·30	34	− 1	15
57	138·69	305	691	26	147	47·41	28	+ 7	14
59	141·16	210	739	22	149	56·61	19	12	12
61	143·77	118	775	17	151	65·90	10	14	9
63	146·53	+ 28	797	− 8	153	75·27	+ 1	13	7
65	149·44	− 59	810	+ 4	155	84·72	− 6	10	4
67	152·51	143	813	17	157	94·25	10	8	2
69	155·73	223	807	32	159	103·84	12	+ 3	+ 1
71	159·12	300	793	48	161	113·49	13	− 1	0
73	162·66	374	774	66	163	123·20	10	3	− 1
75	166·37	444	746	85	165	132·95	8	7	− 1
77	170·24	511	712	104	167	142·75	4	8	0
79	174·28	572	671	125	169	152·59	− 1	9	0
81	178·49	630	624	145	171	162·46	+ 4	9	+ 1
83	182·86	686	572	167	173	172·36	6	8	1
85	187·41	736	514	188	175	182·28	8	8	2
87	192·12	781	449	210	177	192·19	12	5	3
89	197·01	− 824	− 379	+ 231	179	202·16	+ 14	- 4	+ 3

TABLE III.—*continued.*

Third Quadrant. Unit 0·0001.					*Fourth Quadrant.* Unit 0·0001.				
u	g'	a^2X_4du	a^2Y_4du	a^2Z_4du	u	g'	a^2Xdu	a^2Ydu	a^2Zdu
269°	212°·19	+ 152	+ 57	+ 38	359°	302°·09	+ 77	− 39	− 9
267	206·97	143	40	32	357	301·92	70	78	23
265	201·57	132	26	27	355	301·74	59	126	37
263	196·00	119	13	22	353	301·55	42	171	52
261	190·27	106	+ 1	18	351	301·33	− 20	216	68
259	184·36	93	− 8	14	349	301·09	+ 8	261	84
257	178·29	80	15	11	347	300·82	43	303	101
255	172·05	65	21	8	345	300·51	86	344	118
253	165·65	52	26	5	343	300·15	136	377	134
251	159·08	40	28	3	341	299·75	194	404	150
249	152·35	27	30	+ 1	339	299·29	259	418	163
247	145·46	14	29	− 1	337	298·76	329	420	175
245	138·42	+ 4	29	2	335	298·18	400	404	182
243	131·22	− 5	27	2	333	297·51	471	369	185
241	123·87	13	22	3	331	296·78	537	316	182
239	116·37	19	18	3	329	295·96	593	243	173
237	108·72	23	12	2	327	295·05	634	152	156
235	100·93	26	− 5	− 1	325	294·04	658	− 47	134
233	93·00	25	+ 1	+ 1	323	292·94	659	+ 68	105
231	84·93	22	9	4	321	291·74	640	185	72
229	76·73	15	15	6	319	290·43	601	299	− 36
227	68·40	− 6	20	10	317	289·01	544	406	+ 1
225	59·95	+ 5	23	13	315	287·47	473	501	39
223	51·38	17	21	15	313	285·81	390	584	76
221	42·69	28	18	16	311	285·03	302	652	110
219	33·89	35	+ 11	16	309	282·11	208	706	143
217	24·98	36	0	14	307	280·07	113	744	174
215	15·96	33	− 8	11	305	277·89	+ 18	770	201
213	6·85	24	13	8	303	275·57	− 72	783	226
211	357·65	14	16	4	301	273·10	161	785	248
209	348·36	+ 4	15	+ 2	299	270·49	247	777	267
207	338·99	− 3	13	0	297	267·73	327	760	285
205	329·54	8	8	0	295	264·82	402	734	298
203	320·01	11	− 3	0	293	261·75	474	700	311
201	310·42	10	+ 1	0	291	258·53	541	660	321
199	300·77	9	3	+ 1	289	255·14	602	613	330
197	291·06	6	6	2	287	251·60	657	560	334
195	281·31	− 2	7	2	285	247·89	709	503	339
193	271·51	0	7	3	283	244·02	755	440	340
191	261·67	+ 5	7	4	281	239·98	795	374	339
189	251·80	9	6	4	279	235·77	828	302	336
187	241·90	12	5	4	277	231·39	856	228	331
185	231·98	13	+ 3	4	275	226·85	877	149	323
183	222·07	14	0	4	273	222·14	892	+ 69	314
181	212·10	+ 14	− 2	+ 4	271	217·25	− 900	− 14	+ 303

Table IV. gives for argument u

$$\frac{1}{m'}\frac{dn}{n},\ \frac{1}{m'}de,\ \frac{1}{m'}ed\varpi,\ \frac{d\epsilon}{m'}-\frac{d\varpi}{m'}\left\{1-\sqrt{(1-e^2)}\right\} \text{ and } \frac{1}{m'}\frac{dn}{n}(2\pi-nt)$$

The mechanical quadratures for the second and third quadrants require to be supplemented by the definite integrals arising from V_3.

TABLE IV.

First Quadrant.

u	$\frac{1}{m'}\frac{dn}{n}$	$\frac{1}{m'}de$	$\frac{1}{m'}ed\varpi$	$\frac{d\varepsilon}{m'}-\frac{d\varpi}{m'}\{1-\sqrt{(1-e^2)}\}$	$\frac{1}{m'}\frac{dn}{n}\times(2\pi-nt)$
°					
1	+ ·0001	·0000	+ ·0001	·0000	+ ·001
3	− ·0036	+ ·0001	·0001	·0000	− ·023
5	·0073	·0001	·0001	·0000	·046
7	·0112	·0003	·0001	·0000	·070
9	·0151	·0004	·0001	− ·0001	·095
11	·0188	·0004	·0002	·0001	·118
13	·0221	·0005	·0002	·0002	·139
15	·0249	·0005	+ ·0001	·0003	·156
17	·0260	·0006	− ·0001	·0004	·163
19	·0261	·0006	·0005	·0006	·164
21	·0239	·0006	·0011	·0007	·150
23	·0193	·0006	·0019	·0010	·121
25	− ·0114	·0004	·0030	·0012	− ·071
27	·0000	·0003	·0045	·0012	·000
29	+ ·0151	+ ·0001	·0063	·0011	+ ·094
31	·0336	− ·0002	·0083	·0008	·210
33	·0552	·0005	·0104	− ·0001	·344
35	·0783	·0009	·0125	+ ·0010	·488
37	·1019	·0013	·0143	·0026	·634
39	·1238	·0017	·0155	·0048	·769
41	·1425	·0021	·0159	·0075	·884
43	·1566	·0024	·0152	·0104	·969
45	·1651	·0028	·0135	·0135	1·022
47	·1679	·0032	·0108	·0168	1·036
49	·1645	·0036	·0070	·0197	1·013
51	·1555	·0039	− ·0024	·0222	·955
53	·1423	·0043	+ ·0030	·0243	·872
55	·1253	·0047	·0090	·0256	·767
57	·1054	·0052	·0154	·0262	·643
59	·0830	·0056	·0221	·0257	·505
61	·0596	·0061	·0288	·0243	·361
63	·0351	·0067	·0355	·0218	·212
65	+ ·0101	·0074	·0421	·0182	+ ·061
67	− ·0153	·0079	·0485	·0134	− ·092
69	·0404	·0085	·0542	+ ·0072	·242
71	·0654	·0090	·0601	− ·0003	·390
73	·0900	·0095	·0654	·0093	·534
75	·1140	·0100	·0700	·0197	·674
77	·1372	·0104	·0740	·0318	·807
79	·1588	·0106	·0769	·0451	·929
81	·1793	·0108	·0792	·0601	1·044
83	·1990	·0108	·0805	·0768	1·153
85	·2166	·0105	·0808	·0948	1·249
87	·2322	·0101	·0796	·1141	1·331
89	− ·2467	− ·0092	+ ·0775	− ·1349	− 1·405
Sums,	+ ·0163	− ·1744	+ ·8604	− ·3095	+ ·674

TABLE IV.—*continued.*

Second Quadrant.

u	$\frac{1}{m'}\frac{dn}{n}$	$\frac{1}{m'}de$	$\frac{1}{m'}ed\varpi$	$\frac{d\epsilon}{m'}-\frac{d\varpi}{m'}\{1-\sqrt{(1-e^2)}\}$	$\frac{1}{m'}\frac{dn}{n}\times(2\pi-nt)$
91°	+·0311	−·0025	+·0040	+·0257	+·176
93	·0312	·0022	·0023	·0265	·176
95	·0307	·0018	+·0010	·0272	·172
97	·0294	·0014	−·0002	·0269	·163
99	·0277	·0010	·0014	·0266	·153
101	·0256	·0007	·0022	·0256	·140
103	·0232	−·0004	·0030	·0239	·126
105	·0208	·0000	·0036	·0223	·112
107	·0176	+·0003	·0040	·0194	·094
109	·0151	·0006	·0042	·0170	·080
111	·0119	·0008	·0043	·0136	·062
113	·0089	·0011	·0043	·0098	·046
115	·0059	·0011	·0039	·0060	·030
117	·0035	·0012	·0035	+·0026	·018
119	+·0011	·0012	·0028	−·0010	+·006
121	−·0010	·0011	·0021	·0044	−·005
123	·0026	·0010	·0013	·0070	·013
125	·0039	·0006	−·0004	·0093	·019
127	·0047	+·0003	+·0004	·0108	·023
129	·0049	−·0002	·0013	·0107	·023
131	·0045	·0007	·0021	·0090	·021
133	·0034	·0011	·0025	·0057	·016
135	−·0017	·0015	·0026	−·0005	−·008
137	+·0003	·0017	·0023	+·0060	+·001
139	·0024	·0016	·0015	·0126	·011
141	·0043	·0012	+·0004	·0181	·019
143	·0052	−·0007	−·0006	·0205	·023
145	·0057	·0000	·0017	·0219	·025
147	·0050	+·0007	·0022	·0179	·021
149	·0037	·0011	·0021	·0121	·015
151	·0024	·0011	·0018	·0061	·010
153	+·0010	·0012	·0012	+·0001	+·004
155	−·0001	·0009	·0005	−·0046	·000
157	·0006	·0007	−·0001	·0074	·002
159	·0011	+·0003	+·0004	·0088	·004
161	·0014	−·0001	·0008	·0095	·005
163	·0011	·0003	·0007	·0073	·004
165	·0011	·0007	·0008	·0058	·004
167	·0009	·0008	·0005	·0028	·003
169	·0008	·0009	·0004	−·0006	·003
171	·0005	·0009	+·0001	+·0032	·002
173	·0004	·0008	−·0001	·0047	·001
175	·0004	·0008	·0003	·0063	·001
177	·0002	·0005	·0005	·0093	·001
179	−·0002	−·0004	−·0007	+·0108	−·001
Sums,	+·2782	−·0096	−·0289	+·3175	+1·524

TABLE IV.—*continued.*

Third Quadrant. V_4 only.

u	$\frac{1}{m'}\frac{dn}{n}$	$\frac{1}{m'}de$	$\frac{1}{m'}ed\varpi$	$\frac{d\epsilon}{m'}-\frac{d\varpi}{m'}\{1-\sqrt{(1-e^2)}\}$	$\frac{1}{m'}\frac{dn}{n}\times(2\pi-nt)$
269°	− ·0455	+ ·0015	− ·0022	+ ·0333	− ·028
267	·0426	·0011	·0033	·0327	·028
265	·0392	·0007	·0043	·0316	·027
263	·0353	+ ·0003	·0050	·0297	·026
261	·0314	− ·0001	·0056	·0275	·024
259	·0275	·0004	·0060	·0250	·022
257	·0237	·0007	·0061	·0223	·020
255	·0192	·0009	·0061	·0186	·018
253	·0155	·0012	·0060	·0152	·015
251	·0120	·0013	·0056	·0118	·012
249	·0084	·0015	·0052	·0077	·009
247	·0048	·0014	·0044	+ ·0033	·005
245	− ·0020	·0015	·0038	− ·0003	− ·002
243	+ ·0004	·0014	·0032	·0038	·000
241	·0026	·0012	·0021	·0069	+ ·003
239	·0042	·0009	·0012	·0096	·005
237	·0053	·0006	− ·0002	·0114	·007
235	·0062	− ·0002	+ ·0009	·0128	·009
233	·0060	+ ·0002	·0015	·0123	·009
231	·0055	·0007	·0023	·0111	·008
229	·0041	·0010	·0026	·0071	·006
227	·0023	·0014	·0027	− ·0021	+ ·004
225	+ ·0001	·0016	·0024	+ ·0042	·000
223	− ·0023	·0015	·0015	·0111	− ·004
221	·0045	·0013	+ ·0005	·0177	·006
219	·0059	+ ·0008	− ·0007	·0220	·011
217	·0065	− ·0001	·0019	·0225	·012
215	·0062	·0008	·0026	·0207	·012
213	·0047	·0012	·0026	·0150	·010
211	·0032	·0014	·0022	·0085	·007
209	·0016	·0013	·0015	+ ·0020	·003
207	− ·0005	·0012	·0009	− ·0027	− ·001
205	+ ·0004	·0007	− ·0002	·0059	+ ·001
203	·0011	− ·0003	+ ·0004	·0080	·003
201	·0012	+ ·0001	·0006	·0072	·003
199	·0011	·0003	·0007	·0065	·003
197	·0009	·0006	·0006	·0042	·002
195	·0007	·0007	·0005	− ·0013	·002
193	·0005	·0007	+ ·0003	+ ·0002	·001
191	·0002	·0007	− ·0001	·0039	+ ·001
189	+ ·0001	·0006	·0003	·0070	·000
187	·0000	·0005	·0005	·0093	·000
185	− ·0001	+ ·0003	·0006	·0100	·000
183	·0002	·0000	·0007	·0108	− ·001
181	− ·0003	− ·0002	− ·0007	+ ·0108	− ·001
Sums,	− ·3002	− ·0039	− ·0683	+ ·3212	− ·237

TABLE IV.—*continued.*

Fourth Quadrant.

u	$\frac{1}{m'}\frac{dn}{n}$	$\frac{1}{m'}de$	$\frac{1}{m'}ed\varpi$	$\frac{de}{m'}-\frac{d\varpi}{m'}\{1-\sqrt{(1-e^2)}\}$	$\frac{1}{m'}\frac{dn}{n}\times(2\pi-nt)$
359°	+·0034	−·0001	+·0001	·0000	·000
357	·0070	·0001	·0001	·0000	·000
355	·0111	·0002	·0001	·0000	·000
353	·0144	·0003	·0002	·0000	·000
351	·0172	·0004	·0001	−·0001	·000
349	·0190	·0004	+·0001	·0001	·000
347	·0196	·0004	−·0001	·0002	·000
345	·0186	·0005	·0003	·0003	·000
343	·0156	·0004	·0007	·0004	·000
341	·0102	·0003	·0012	·0005	·000
339	+·0019	−·0001	·0020	·0005	·000
337	−·0091	+·0001	·0030	·0006	·000
335	·0228	·0003	·0041	·0005	−·001
333	·0391	·0005	·0054	−·0002	·001
331	·0570	·0008	·0067	+·0003	·002
329	·0767	·0012	·0080	·0011	·003
327	·0939	·0016	·0089	·0023	·005
325	·1103	·0019	·0094	·0037	·006
323	·1230	·0022	·0092	·0055	·008
321	·1318	·0025	·0083	·0075	·009
319	·1355	·0027	·0065	·0096	·011
317	·1339	·0029	·0040	·0116	·012
315	·1273	·0032	−·0006	·0135	·013
313	·1159	·0034	+·0035	·0150	·013
311	·1010	·0037	·0081	·0160	·013
309	·0824	·0039	·0132	·0164	·011
307	·0612	·0041	·0187	·0160	·009
305	·0380	·0043	·0243	·0149	·006
303	−·0144	·0046	·0299	·0128	−·003
301	+·0106	·0048	·0355	·0099	+·002
299	·0361	·0052	·0409	·0056	·008
297	·0611	·0054	·0461	+·0005	·015
295	·0857	·0057	·0506	−·0059	·022
293	·1101	·0060	·0548	·0136	·031
291	·1335	·0061	·0584	·0226	·040
289	·1556	·0062	·0613	·0327	·051
287	·1760	·0062	·0633	·0441	·062
285	·1956	·0061	·0647	·0567	·073
283	·2132	·0058	·0650	·0707	·086
281	·2287	·0053	·0644	·0855	·098
279	·2417	·0047	·0626	·1010	·111
277	·2528	·0038	·0597	·1175	·123
275	·2611	·0027	·0556	·1345	·136
273	·2669	+·0013	·0504	·1517	·147
271	+·2700	−·0004	+·0440	−·1688	+·158
Sums,	+1·3634	+·1156	+·8973	−·8465	+1·037

In order to calculate the definite integrals arising from V_3 for $u = 90°$, 180°, and 270° (the middle value is given in addition to what is strictly necessary, in order to give the results for the second and third quadrants separately), the quantities given in the first half of p. 409 are applicable.

We have in addition—

	$u = 90°$	$u = 180°$	$u = 270°$
g'	199°·52	207°·13	214°·74
$\frac{x'}{a}$	+ ·524	+ ·536	+ ·540
$\frac{y'}{a}$	+ ·175	− ·110	+ ·043
$\frac{1}{na}\frac{dx'}{dt}$	+ ·310	+ ·149	+ ·001
$\frac{1}{na}\frac{dy'}{dt}$	− 1·222	− 1·263	− 1·285
$\frac{1}{m'}\cdot\frac{1}{n}\int dn$	− 0·68	− 1·598	− 1·40
$\frac{1}{m'}\int de$	− 0·387	− 0·665	− 0·351
$\frac{1}{m'}\, e\int d\varpi$	+ 1·16	− 0·094	− 1·36
$\frac{1}{m'}\left[\int d\zeta + \sqrt{(1-e^2)}\int d\varpi - \frac{2\pi - nt}{n}\int dn\right]$	+ 3·32	+ 0·600	− 2·76

Hence

Quadrant.		$\frac{1}{m'}\frac{1}{n}\int dn$	$\frac{1}{m'}\int de$	$\frac{1}{m'}\int e\,d\varpi$
I.	V .	+ 0·01 63	− 0·17 44	+ 0·86 04
II.	V_4 .	+ 0·27 82	− 0·00 96	− 0·02 89
II.	V_3 .	− 0·92	− 0·27 8	− 1·25
III.	V_4 .	− 0·30 02	− 0·00 39	− 0·06 83
III.	V_3 .	+ 0·18	+ 0·31 4	− 1·27
IV.	V .	+ 1·36 34	+ 0·11 56	+ 0·89 73
	Sum	+ 0·62	− 0·03 6	− 0·86

Substituting $m' = \frac{1}{3501\cdot6}$

$$\frac{1}{n}\int dn = + \cdot000\ 177 \qquad \int de = - \cdot000\ 010 \qquad \int d\varpi = - \cdot000\ 254 \text{ radians.}$$

De Pontécoulant's results are

+ ·000 129	− ·001 105	− ·000 230

To calculate $\int d\zeta$

Quadrant	$\frac{1}{m'}\int \frac{dn}{n}(2\pi - nt)$	$\frac{\int d\epsilon}{m'} - \frac{\int d\varpi}{m'}\left\{1 - \sqrt{(1-e^2)}\right\}$	$e\frac{\int d\varpi}{m'}$
I. .	+0·674	− ·30 95	+ ·86 04
II. .	+1·524	+ ·31 75	− ·02 89
III. .	−0·237	+ ·32 12	− ·06 83
IV. .	+1·037	− ·84 65	+ ·89 73
Sums	+2·998	− ·51 73	+1·66 05

Hence $\frac{1}{m'}\int d\zeta$ (mechanical quadratures only)

$$= +2\cdot998 - 0\cdot517 - \cdot436 = +2\cdot05$$

Again

$$\frac{1}{m'}\left[\int d\zeta + \sqrt{(1-e^2)}\int d\varpi - \frac{2\pi - nt}{n}\int dn\right]_{u=90°}^{u=270°} \quad . \quad . \quad . \quad = -6\cdot08$$

$$-\frac{\sqrt{(1-e^2)}}{e} \times \frac{e\int d\varpi}{m'} \text{ between limits} \quad . \quad . \quad . \quad . \quad = +0\cdot66$$

$$\frac{1}{m'}\frac{2\pi - nt}{n}\int dn \text{ at upper limit} = -1\cdot40 \times 0\cdot6036 \quad . \quad . \quad = -0\cdot85$$

$$-\text{ditto at lower limit} = -(-0\cdot68) \times 5\cdot6796 \quad . \quad . \quad = +3\cdot86$$

Sum $\quad -2\cdot41$

Hence $\frac{1}{m'}\int d\zeta$ (V_3 only) $= -2\cdot41$

$$\frac{1}{m'}\int d\zeta = -0\cdot36 \text{ (complete value),}$$

or putting $m' = \frac{1}{3501\cdot6}$

$$\int d\zeta = -\cdot000\ 103 \text{ radians.}$$

De Pontécoulant gives −·000628 radians.

Hence his value of the next perihelion passage, considering the action of Saturn only, is two days later than ours. De Pontécoulant's eccentricity is again certainly in error; presumably

the same (or approximately the same) factor has been omitted as in the case of Jupiter.

Errata in previous Paper.

Page 386, $e_x = -(1-e^2)\sin u \cos u$.

Page 393, *read* η' *for* y' in the value of $\frac{x'}{a}$.

Page 411, second line, *read* $-0{\cdot}001129$ *for* $-0{\cdot}000273$; hence, third line, *read* $+0{\cdot}147631$ *for* $+0{\cdot}148487$,

$$\int d\zeta = +{\cdot}15506 \text{ for } +{\cdot}15592 \text{ radians.}$$

Last line, *for* thirteen days *read* nine days.

Observations of Comets d, e, and g 1906, *from Photographs taken with the 30-inch Reflector of the Thompson Equatorial at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The following positions of Comets *d*, *e*, and *g*, 1906, were obtained from photographs taken with the 30-inch Reflector.

The plates were measured with the astrographic micrometer. Six reference stars were, as a rule, measured with the Comet, their positions being derived when possible from the Catalogues of the Astronomische Gesellschaft.

The positions given are not corrected for Parallax.

log Parallax Correction = log Parallax Factor − log Δ.

Comet *d* 1906.

Date and G.M.T. 1906.				Apparent R.A.			Apparent Dec.			Log. Parallax Factor. R.A.	Dec.
	d	h	m	s	h	m	s	°	′	″		
July	25	13	59	38	0	43	30·75	− 8	58	20·3	−9·358	+0·872
	31	14	7	57	1	35	5·93	− 4	19	2·5	−9·399	+0·854
Aug.	1	14	5	57	1	44	7·08	− 3	27	42·2	−9·412	+0·850
	3	13	59	54	2	2	21·04	− 1	42	58·7	−9·442	+0·843
	3	14	21	36	2	2	29·32	− 1	42	11·0	−9·402	+0·843
	4	13	53	12	2	11	30·43	− 0	49	56·6	−9 459	+0·839
	4	14	8	10	2	11	36·04	− 0	49	19·2	−9·436	+0·839
	14	14	11	10	3	40	36·13	+ 7	37	57·9	−9·504	+0·808
	15	14	23	15	3	48	52·33	+ 8	22	15·6	−9·496	+0·803
	19	14	55	33	4	19	59·80	+11	1	30·2	−9·477	+0·786
	27	14	17	43	5	12	40·71	+14	56	14·7	−9·547	+0·785
	28	14	21	16	5	18	30·25	+15	19	1·4	−9·547	+0·783
Sept.	1	14	48	29	5	40	16·79	+16	37	58·2	−9·530	+0·767
	25	15	16	08	7	13	11·97	+20	10	58·4	−9·565	+0·763
	26	14	49	5	7	16	1·49	+20	14	12·5	−9·537	+0·743
Oct.	16	15	33	34	8	1	39·08	+20	49	14·0	−9·421	+0·696
	27	16	39	11	8	17	18·34	+21	5	31·8	−9·106	+0·656

Comet *e* 1906.

Date and G.M.T. 1906. d h m s	Apparent R.A. h m s	Apparent Dec. ° ′ ″	Log. Parallax Factor. R.A.	Dec.
Aug. 28 12 24 28	22 45 5·33	+10 6 34·7	+7·909	+0·762
29 13 22 15	22 44 17·63	+10 2 20·7	+9·036	+0·766
Sept. 11 10 51 47	22 35 1·48	+ 8 54 23·6	−8·570	+0·773
25 10 24 13	22 28 7·13	+ 7 17 52·0	+8·248	+0·785
26 11 5 37	22 27 47·95	+ 7 10 40·3	+8·958	+0·788
27 10 26 39	22 27 31·62	+ 7 3 53·5	+8·549	+0·787
27 10 56 57	22 27 31·15	+ 7 3 44·1	+8·927	+0·789

Comet *g* 1906.

Nov. 17 13 5 42	9 47 58·07	+21 6 24·8	−9·578	+0·768
22 14 9 10	10 15 26·06	28 3 29·9	−9·558	+0·679
Dec. 10 13 50 55	12 25 54·32	50 4 6·1	−9·749	+0·562
12 13 55 23	12 42 49·47	51 43 23·4	−9·766	+0·553
21 12 59 28	13 57 37·79	56 51 2·3	−9·811	+0·692
1907. Jan. 17 11 49 51	16 31 15·30	60 46 4·7	−9·730	+0·826

Observations of Jupiter during the apparition of 1906–7.
By Rev. T. E. R. Phillips.

During the past apparition I was able to observe the planet on 106 occasions. The instrument used was a $9\frac{1}{4}$-inch equatorial reflector, the large mirror of which (originally by With) has been recently refigured by Mr Calver. Somewhat curiously—considering the exceedingly favourable position of the planet—atmospheric troubles proved unusually annoying, especially when observations were made before midnight. No doubt the somewhat low position of the instrument is partly accountable for this state of things, but there can be no question that the atmosphere was commonly much disturbed, and during the spring months the prevalence of cloud was almost abnormal. Owing to this latter cause observations had practically to be discontinued at the beginning of May.

The following are the particulars of the planet's position, etc. on the date of "opposition."

Date of "Opposition."	R. A. h m s	Dec. ° ′ ″	Equatorial Diameter. ″	Latitude of Centre of Disc. °
1906 Dec. 28	6 26 14	+23 12 50	47·8	+1·97

General Remarks on the Appearance of the Disc.

(1) *Surface Markings.*—The most notable change, as compared with the previous apparition, was the great development of the N. equatorial belt. It may be remembered that at the beginning of

1906 this belt was so feeble as to be little more than the N. edge of a slaty-blue shading, which at that time covered the N. part of the equatorial zone. The first indication of the great change that subsequently occurred was observed by Mr W. F. Denning, who in April found a very dark spot close to the S. edge of the N. temperate belt, and connected with the N. equatorial belt by a slanting streak. This spot seemed to be the centre of an eruption from which a large quantity of dark matter passed *via* the slanting streak into the N. equatorial belt. Unfortunately, the planet was then approaching conjunction with the Sun; but when observations were resumed in August, it was at once seen that a complete transformation had taken place. The N. equatorial belt then obviously exceeded the S. equatorial belt in breadth, and was distinguished by a remarkable series of alternate gaps or white rifts and very dark reddish streaks along its S. edge. These streaks were connected by delicate wisps with dark spots at the N. edge of the S. equatorial belt. Later in the apparition the N. equatorial belt was clearly seen to be triple, but the S. component was much the darkest of the three.

The great S. tropical disturbance was again an interesting feature of the disc. Its f. portion was still in conjunction with the red spot when observations were commenced in August, but the p. end, which had been very vague and ill-defined during the earlier part of the year, had regained all its former sharpness and clearness. The dark matter, as measured along the S. temperate belt, extended over nearly 60° of longitude at the commencement of the observations, but diminished to something like 47° by the end of the apparition. The length, as measured along the S. equatorial belt, was rather less. The p. and f. white spots were still conspicuous objects.

The old red spot was quite plainly seen on several occasions. It commonly presented the aspect of a faint elliptical grey shading which was lighter in the middle. The darkest portion was near the f. end, as has usually been the case in recent years, but in the moments of best seeing the dusky streak at its s.f. border appeared quite separated from the f. "shoulder" of the bay. There was also a wisp connecting the p. end of the spot with the S. temperate belt and the p. "shoulder." The well-known bay or hollow in which the red spot lies was again a well-defined object, with the exception that during the earlier part of the apparition the S. component of the S. equatorial belt was very narrow and very faint at and for some distance in front of the p. "shoulder."

(2) *Colour Changes.*—A conspicuous change of colour, as compared with the apparition of 1905–6, was exhibited by the N. equatorial belt. Distinctly bluish before the planet's conjunction with the Sun, it was decidedly red when observations were recommenced in August. A few months later the S. edge was still intensely red, almost brick-red in tone, but the central portion of the belt had faded to yellowish-red, and the N. edge to grey or even bluish-grey.

The S. equatorial belt, which during the previous apparition had been purplish, usually seemed wanting in distinctive colouring, but occasionally traces of purple or reddish-purple were seen, especially in the region following the f. "shoulder" of the red spot bay.

The whole of the disc from the N.N. temperate belt to the N. pole was commonly bluish-purple, whereas during the apparition of 1895–6 the N. polar regions had been reddish.

Rotation Periods.

My chief endeavour during the period covered by the observations was to secure as large a number as possible of eye-estimated transits of spots and other markings over the central meridian of the illuminated disc, with a view to determining the mean rotation period in different latitudes. About 1550 such transits were obtained, and on reducing them and charting the longitudes I found that about 90 objects had been sufficiently well observed to leave little doubt as to the identifications. The deduced mean values of the rotation periods of spots situated in the principal surface currents are given in the accompanying table.

Table of Rotation Periods.

	Current.	No. of Spots observed.	Mean No. of Observations.	Mean No. of Rotations.	Rotation Period. h	m	s
	South South Temperate Belt	1	11	171	9	55	10·9
	Bright and dark spots at S. edge of South Temperate Belt	20	10	375	9	55	21·8
Great South Tropical Disturbance.	*Preceding* white spot	1	23	639	9	55	22·9
	Preceding end of dark matter (at S. Temp. belt)	1	32	644	9	55	22·6
	Preceding end of dark matter (at S. Equat. belt)	1	21	434	9	55	23·5
	Following end of dark matter (at S. Temp. belt)	1	26	610	9	55	21·1
	Following end of dark matter (at S. Equat. belt)	1	16	355	9	55	21·3
	Following white spot	1	21	478	9	55	21·3
	Means for whole S. Tropical disturbance	6	23	527	9	55	22·1
	Great Red Spot Hollow	1	34	589	9	55	42·2
	White and dark South Equatorial spots	36	15·5	391	9	50	27·1
	White and dark North Equatorial spots	18	14	310	9	50	41·8
	Spots on North North Temperate belt	7	10	308	9	55	41·7
	Spots within N. Polar shading	2	10	257	9	55	40·6

Remarks on the Rotation Periods and the Movements of Spots.

S.S. Temperate Belt.—The value here given is somewhat longer than that usually exhibited by spots situated in the great southern current. One or two transits were secured earlier in the apparition, which quite possibly belonged to the object observed, and which would make the period about normal ($9^h\ 55^m\ 6^s \pm$). The identification is however uncertain, owing to a rather long gap in the observations, and the transits mentioned have consequently not been used in the reduction.

Spots at S. edge of South Temperate Belt.—The period of this current is also some two or three seconds longer than that usually found, but the number of spots observed is so large that there can be very little doubt as to the reality of the slight retardation indicated.

The Great Red Spot.—The rotation period of this object and of the hollow in which it lies has been notoriously variable during the last few years, especially about the times when the great S. tropical disturbance, which is situated in the same latitude and has a quicker motion, has been in conjunction with it. Conjunctions took place in 1902, 1904, and 1906, and on each occasion the effect of the dark material sweeping past the red spot has been to accelerate temporarily the latter's rotational velocity. This was especially marked last year. Thus in April 1906 the longitude of the red spot was about 29°, but when observations were recommenced in the second week in August it was found that the longitude had diminished to something like 15°·5. So rapid a shift had not previously been observed in connection with the red spot. It is further noteworthy that the very marked rotational acceleration which the shift of longitude denotes had by that time entirely ceased, and was subsequently followed by a decided retardation. By the beginning of May 1907 the longitude of the red spot and hollow had increased to rather over 24°.

The Great S. Tropical Disturbance.—It will be remembered that Major Molesworth, as the result of certain computations, has suggested an interesting hypothesis as regards the manner of the passage of the S. tropical disturbance from the f. to the p. side of the red spot. This passage undoubtedly takes place *via* the S. temperate belt, but the special point in Major Molesworth's contention is that the apparent transference of matter is practically instantaneous. In other words, instead of the p. end of the disturbance occupying between two and three months in passing round the S. edge of the spot, he believes that almost immediately it comes up to the f. "shoulder" of the bay, dark matter appears above the p. "shoulder." It is as if the material of the S. temperate belt were incompressible, so that as soon as the dark substance of the great disturbance enters it, it displaces an equal quantity at the other end.

An opportunity of partially testing this hypothesis by actual

observations seemed to present itself at the time of the 1906 conjunction, but an unexpected difficulty arose through the extreme faintness and indefinite character of the dark matter which first appeared on the p. side of the red spot. Thus the p. end of the disturbance was observed to arrive at the f. "shoulder" ($\lambda = 47^{\circ}{\cdot}5$ Syst. ii.) about Feb. 25, and the region above the p. "shoulder" ($\lambda = 10^{\circ} \pm$) was immediately watched. The expected dusky material, however, did not make its appearance, or at any rate it was not sufficiently intense to be observed. But later on, in the early part of April, it became obvious that the S. tropical zone above and in front of the p. "shoulder" had lost something of its white appearance, though it was not as yet possible to feel sure of the existence there of the stream of dark matter. By the middle of the month, however, all doubt had vanished, and the p. end of the disturbance was clearly discerned in about $\lambda\, 355^{\circ}$. Now, working backwards from the observed rate of motion during the apparition just closed, it appears that this must have been just about the longitude at the middle of April; and further, that the p. end of the disturbance, supposing it to have been moving at a uniform rate, must have been at the p. "shoulder" about March 11.

According to this computation, then, the p. end traversed the distance between the two "shoulders" of the bay—some 37°—in only fourteen days, instead of occupying nearly three months in the transit!

An investigation of the motion of the f. end of the disturbance gives a closely similar result. As above mentioned, the red spot hollow exhibited a quite abnormally large shift in longitude during the time of the planet's invisibility; and at the resumption of observations the longitude of the f. "shoulder" was only about 34°, and that of the p. "shoulder" about 357°. On the occasion of my first observation in the new apparition (1907 August 10) the dusky wisp connecting the end of the red spot with the f. "shoulder" was so dark and broad as to give the impression that it was in reality the f. end of the great S. tropical disturbance just arriving at the f. "shoulder" of the bay, and an entry to this effect was made in my observation-book. This surmise is confirmed by the fact that, assuming a constant rate of motion, the f. end of the disturbance was due in this longitude about August 7, only a very few days before the observation above mentioned. Now, the first few observations I was able to secure of the f. end of the disturbance after its appearance on the p. side of the red spot make it clear that Aug. 22 was about the date of its conjunction with the p. "shoulder." This means that the f. end of the disturbance traversed the length of the red spot bay between approximately August 10 and 22, instead of occupying nearly three months in the process.

On the whole, therefore, it seems that my observations confirm the main point of Major Molesworth's theory, though indicating an interval of about two weeks as needed for the apparent transference of the dark matter from the f. to the p. side of the red spot.

Equatorial Spots.—The motion of both S. and N. equatorial spots varied considerably during the course of the apparition, a decided acceleration of S. equatorial spots between longitudes 0° and 210° ± (System i.), and of N. equatorial spots in almost all longitudes, setting in towards the end of January. There was a very large difference of rate—amounting to over 14 seconds per rotation—between the two portions of the equatorial current.

Description of an Equatorial Reflecting Telescope driven by a Hydraulic Ram. By T. E. Heath.

The drawing shows the optical axis of the telescope pointing to the pole.

A, reflecting telescope (8½″ mirror) in square teak tube.

B, cast-iron right ascension circle 21″ dia., having a groove formed round periphery.

C C, cast-iron A frames bolted to R.A. circle, carrying declination axis, and allowing telescope to be set at any declination from 40° S. to 90° N.

D, cast-iron circle, carrying steel balls upon which the R.A. circle revolves.

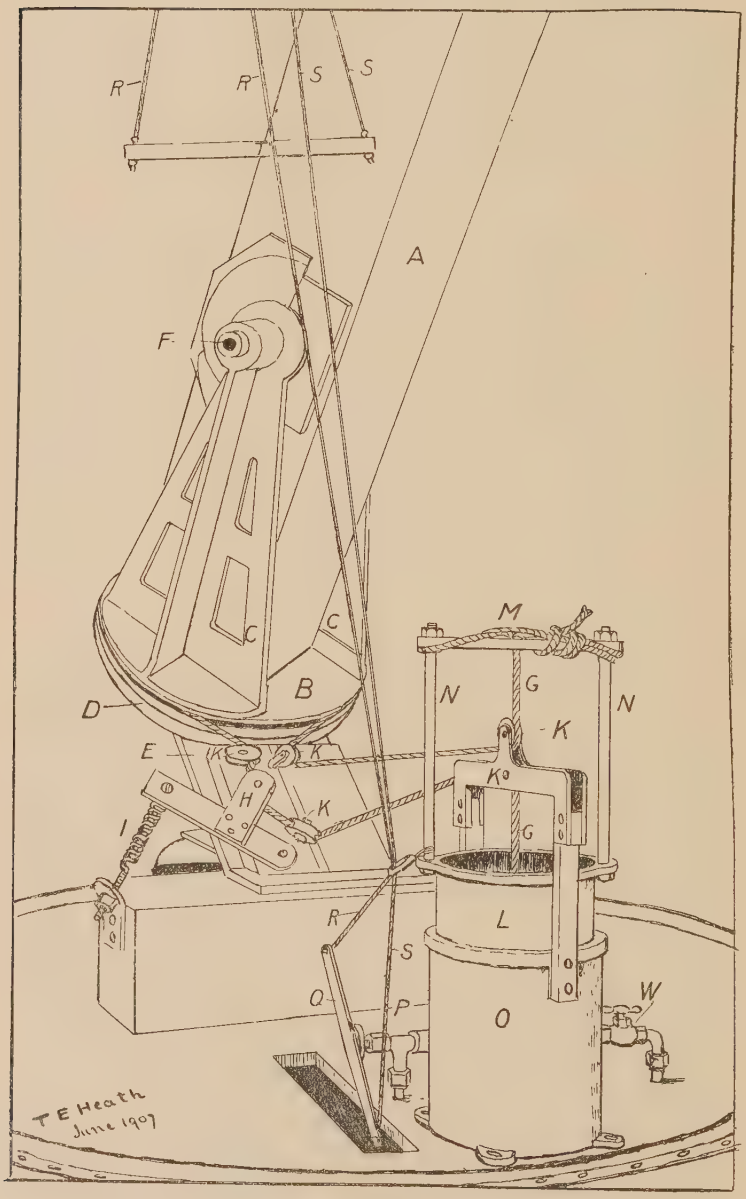
E, cast-iron base-plate, to which D is bolted.

F, declination axis.

G, rope, which fits bottom of the groove in R.A. circle and is kept taut by a tension pulley carried by a lever H which is pulled by a spiral spring I. The rope passes over guide pulleys K, and one end of it is attached to the bottom of a hollow brass hydraulic piston L and the other end to a cross-bar M, which is supported at a sufficient height above the piston L by the pillars N. O is a brass hydraulic cylinder, 8″ dia. and 10″ high. (The piston L has a cup-leather below it.) The supply of liquid to the cylinder is regulated by a valve P (which is one of those sold to regulate the supply of oxygen from a cylinder). The valve is operated by a lever Q, to one end of which is attached a cord R and to the other end a cord S. The cords R and S are led over suitable guides to either end of a bar T, which hangs from the roof of the observatory, conveniently near to the observer.

The telescope is balanced by about 10 lbs. of lead attached to the lower end of the tube, so that it will stay at whatever declination it is set, and so that the force required to move it in R.A. is everywhere approximately the same.

I find that if the rope G be so large that it covers the bottom of the groove in the R.A. circle, but not so great that it grips the sides, and the spiral spring be an ordinary "door pull," then the friction will not prevent the observer easily setting the telescope on any required star, but will be sufficient when he lets go the telescope to cause the R.A. circle to revolve.



Equatorial Reflecting Telescope driven by a Hydraulic Ram.

In practice, the liquid is allowed to flow into the hydraulic cylinder all the time the observer is working. He shifts, as desired, from star to star, and the telescope follows automatically. The hydraulic cylinder is large enough to run the telescope for 2½ hours (it could be made longer if desired). A relief valve marked W is opened, and by standing on the piston it is pressed down, ready for a fresh start. This takes about one minute. It takes less than five minutes from the time I leave the house to the time the telescope is following an easily visible star.

At present I use the water direct from the town supply. This does well enough for observing, as it is quite easy, by means of the bar T, to regulate the supply of water to suit the varying pressure. For photographic work, it would be desirable to draw the supply of liquid from a high tank, in which the level is kept constant by a ball valve, and it would be preferable to use glycerine or something not easily frozen. (2½ hours' supply is about one gallon.)

On May 27 I found Jupiter with the circles at 5·50 p.m., and followed it till 9·5 p.m., when it set behind trees. I had several times to vary the supply of water, but sometimes the telescope would run truly for 30 minutes. I had, of course, to empty the cylinder once. The motion is absolutely steady. You can get an even sweep in either direction by turning on more or less water. Then, when a suspected object comes across the field, you can go slow and stop it in the middle.

The observatory runs round upon a circular railway attached to the floor. In each corner, forming part of the structure, is a triangular cupboard. Thus the eyepieces, etc. are always handy.

The cost was approximately as follows:—

Mirror, eyepieces, tube, etc., £35; the equatorial stand, £10; the hydraulic clock, £6; and the observatory £10. This, of course, does not include my time, but I did not do any of the manual work.

P.S.—I have improved the working of the inlet valve by screwing a wooden sheave, 9 in. diameter, to the outer face of the lever Q. The cords R and S are fastened to the sheave and wound round it before being taken to the observer.

The Origin of certain Bands in the Spectra of Sun-spots.

By A. Fowler.

In the spectra of sun-spots there are numerous short hazy lines, termed "band lines" or "umbra lines," which have not hitherto been traced to their source. They are especially notable in the neighbourhood of *b*, and on the more refrangible side of this group, and the positions of some of them have been estimated by various observers, including Maunder, Cortie, Hale, Newall, and myself. The close resemblance between these lines and the structure lines of a banded spectrum seen under high dispersion led me to make numerous experiments on banded spectra during 1905 and 1906, with the hope of identifying the substance producing them, but the results were then entirely negative.* I have lately discovered, however, that a great number of these lines really form part of a fluted spectrum, and are to be accounted for by the presence of a compound of magnesium and hydrogen in the umbræ of spots. Pending a more complete comparison, which will take a considerable time, the present preliminary note may be useful to those engaged in the investigation of spot spectra.

The magnesium-hydrogen flutings were the subject of an extended research by Liveing and Dewar many years ago,† when it was clearly shown that hydrogen and magnesium were together involved in their production. Independent evidence as to the existence of a compound of these two elements has since been obtained,‡ and there need be no hesitation in attributing the flutings in question to the chemical combination "magnesium hydride."

The brightest of these flutings, or rather groups of flutings, begins in the green near 5211 and fades off towards the violet, while there is another group beginning near 5620, and another on the violet side of H_β. In a series of experiments made by Mr Howard Payn and myself,§ they appeared very strongly in the spectrum of the arc between magnesium poles in a vessel exhausted to a pressure of a few millimetres, the hydrogen necessary for their formation being liberated in sufficient quantity from the heated poles. A re-examination of the photographs obtained in this way was suggested by a second reading of Mr Newall's account¶ of his observations of a fluting in spot spectra beginning at 5210·2 or

* *Trans. Int. Solar Union*, vol. i. p. 217 (1906).
† *Proc. Roy. Soc.*, vol. xxxii. p. 189 (1881).
‡ Winkler, *Ber. Deutsch. Chem. Gesell.*, vol. xxiv. p. 1973 (1891).
§ *Proc. Roy. Soc.*, vol. lxxii. p. 254 (1903).
¶ *Monthly Notices*, vol. lxvii. p. 170 (1906).

5211·0 *; and although the dispersion was comparatively small, the general resemblance to the spot bands was so striking as to encourage further inquiry.

The 5211 group has accordingly been photographed with a more powerful spectrograph, giving about five-tenth metres to the millimetre in the region of *b*, and new determinations of wave-lengths have been made. Many of the components of the flutings which appeared as single lines with the smaller dispersion are now shown to be double or triple, exactly as they appear in the spot spectrum at corresponding wave-lengths.

The identification might be considered an extremely probable one by comparison with the various visual observations of the spots, but it is rendered quite certain by reference to the magnificent photographs of the spot spectrum which have been obtained at Mount Wilson.† The correspondence would be best shown by photographs of the two spectra on the same scale, but a grating was not available for the magnesium hydride spectrum, and an exact superposition cannot yet be made. Nevertheless, through the medium of a solar spectrum taken with the same instrument as the flutings, the relation can be closely followed.

The first part of the 5211 group agrees remarkably well with Mr Newall's description of the corresponding spot fluting and with the photographic map, the fluting in each case fading off rather rapidly in the direction of *b*. A second fluting, with its head near the more refrangible edge of b_1, is also clearly indicated in the spot photographs, while the well-known double umbra lines about 5163, 5160, and 5157 are also well represented by components of the flutings. Compared in this way, the apparent coincidences are so numerous as to make the identification almost independent of precise determinations of wave-lengths.

A comparison of wave-lengths, however, so far as it can at present be made, leaves no doubt as to the magnesium hydride origin of most of the spot bands in the region considered. A complete catalogue of the band lines in spots is not yet available; many of them are doubtless masked by superposition upon the stronger Fraunhofer lines, and numerous others which appear in the photographs are not yet included in the Mount Wilson tables. Still, as will appear from the following abridged table, giving *provisional* wave-lengths for some of the brighter components of the magnesium hydride flutings, and references to the spot spectrum, there is abundant justification for the identification in question. It will be seen that some of the fluting components are not represented in the list of spot wave-lengths, but it is believed that all of them can be traced in the photographic map, unless hidden by Fraunhofer lines.

* Umbra lines about these positions appear in my own catalogue, but I had not previously suspected them to be associated with the head of a fluting.

† *Astrophys. Journ.*, vol. xxiii. p. 11 (1906), and a more recent unpublished map which I owe to the kindness of Professor Hale.

Magnesium Hydride in Sun-spots.

Magnesium Hydride.		Spots.		Remarks.
λ (Approx.)	Intensity.	Fowler.*	Hale.†	
Triple Head. 5211·00	4	11·11, 11·02	11·02	Newall 11·00
10·47	5			Falls on edge of Ti 10·56
09·90	4	10·06, 09·95		Newall 10·2
09·24	2	09·2		
08·43	2			On edge of strong Cr 08·60
07·30	2	07·26		
05·97	2			On edge of strong Cr 06·21
04·37	1–2		Fringe on violet edge of Cr 04·68	
03·61	1–2	03·66	03·66	
03·08	2	03·12, 02·95		
01·82	1–2	01·77	01·80	
01·08	1–2			Combined in spot with Ti 01·26
5200·68	1–2			
5198·90	1–2			Masked by Fe 98·89
98·45	1–2	98·51	98·52	
96·58	1–2			Masked by Cr and Mn
96·24	1–2		Fringe on violet edge of Fe	
85·90	1–2	85·9		
85·14	1–2	85·20	85·21	
82·37	2			
82·08	2	82·12, 82·01		
81·37	3	81·50		
80·70	3	80·75	80·66	
80·12	3			On Fe 80·23
79·18	3	79·29		
78·63	3	78·64	78·67	
77·41	3			On Fe 77·41
5176·94	3	76·95		Spot line in part due to V

* Visual Estimates, *Trans. Int. Sol. Union*, vol. i. p. 208, and *Monthly Notices*, vol. lxv. p. 218.

† Photographic Determinations, *Astrophys. Journal*, vol. xxiii. p. 26.

Magnesium Hydride in Sun-spots—*continued.*

Magnesium Hydride.		Spots.		Remarks.
λ (Approx.)	Intensity.	Fowler.*	Hale.†	
5175·50	3	75·58, 75·42	75·56	
75·06	3	75·10	75·11	
71·21	3	71·19	71·20	
70·74	3	70·77	70·78	
68·67	2–3			Close to Ni 68·83
68·26	2–3	68·36	68·35	
66·09	2–3	66·13		
65·69	2–3			Close to Fe 65·69
63·25	3–4	63·0*d*	63·10 very broad	
62·89	3–4			
60·30	2–3	60·2	60·39	
59·91	2–3	59·8	59·96	
57·07	2–3	57·2	57·20	
56·79	3	56·8		
55·89	1–2			Falls on Ni 55·94
54·84	3			Conspicuous dark place in photographic map
53·85	2			
53·41	3			
50·31	4	50·4	50·36	
49·64	3	49·9	49·67	
46·54	1–2			Falls on Ni 46·66
46·34	3			Conspicuous in photographic map
45·35	1–2			
44·82	1–2			
44·21	1–2		44·21	
43·76	1–2		43·83	
42·91	2			Falls on Ni 42·96
42·57	2			Close to Fe 42·69
41·41	1–2		41·40 (broad)	
40·43	1–2		40·44 (broad)	
38·92	2		38·96 (broad)	
36·55	2		36·65	Conspicuous in photographic map
5136·23	2			

* Visual Estimates, *Trans. Int. Sol. Union*, vol. i. p. 208, and *Monthly Notices*, vol. lxv. p. 218.

† Photographic Determinations, *Astrophys. Journal*, vol. xxiii. p. 26.

Additional photographs, taken with longer exposures, and covering a greater range of the spectrum, are required before it can be ascertained exactly how much of the detail of the spot spectrum is due to magnesium hydride, but there are indications that several hundreds of the umbra lines will be accounted for. The interpretation of the spot spectrum will evidently be greatly simplified by the elimination of the part due to the flutings, which can be made with greater certainty now that their origin has been traced.

The identification is also of interest as supporting the view that the vapours in spots are at a relatively low temperature. The special strengthening of the flame lines of metals in spots determined independently by Professor Hale and myself, and the subsequent detection by Professor Hale of the extreme red flutings of titanium oxide, however, had left little doubt on this point.

As a great number of the umbra lines under consideration were found by Professor Hale to correspond with very faint solar lines tabulated by Rowland, it must be inferred that magnesium hydride not only occurs in spots, but in a less degree in the general reversing layer of the Sun.

I have great pleasure in expressing my obligations to Messrs H. Shaw and E. J. Evans for able and unstinted assistance in carrying out this preliminary investigation under somewhat difficult conditions.

The Spectrum of Mira Ceti in December 1906, *as photographed at Stonyhurst College Observatory.*

Rev. Walter Sidgreaves, S.J.

The short series of photographs of the spectrum of o Ceti obtained during the unfavourable weather of December last consists of 18 plates on eight nights between December 1 and the following January 3. Of these, 13 plates are by the Thorp objective prism and 5 by the Hilger compound prism. Both prisms give only short spectra. Those by the objective extend well beyond the head of the hydrogen series of a star of the 3rd magnitude, with a length of 22 mm. between H_ν and the red end limit. This limit is a little beyond H_β, for the camera cannot conveniently be adapted to the focal curve of the green and yellow rays. The compound prism stops the violet light by absorption, and the spectrum reaches H_ϵ only of the brighter stars. On the other hand, it extends to the yellow sodium lines on an Edwards isochromatic plate, all in good definition, but covering only about 16 mm. on the plate. This prism was the only one in use at the maxima of 1897 and 1898, and the five plates exposed during the recent exceptionally bright maximum serve for comparisons with those of the earlier dates. They are all that can be desired in definition; but unfortunately no one of them was sufficiently over-exposed (slowly trailed) for

a comparison with the hydrogen spectrum given by the objective prism, as will be seen later.

The line-absorption-spectrum of the star's light in 1906 is substantially the same as in 1897 and 1898; but the bands are very much weaker—quite enough to account for the increase of light at this bright maximum. The bands in the neighbourhood of H_β and H_γ are nearly, perhaps quite, absent on our plates of 1906, and will be referred to immediately in connection with the bright hydrogen lines.

The remarkable change in the hydrogen spectrum, noted in the intensity of H_β by all spectroscopic observers of Mira, is accompanied by a decided change in the relative intensities of H_γ and H_δ. On the plates of 1897 and 1898 the intensities of these lines are quite equal, without allowance for the prismatic absorption at H_δ, or the sensibility curve of the film; and on the same quality of plate (Edwards) in 1906 H_γ is distinctly the stronger.

But whether these changes are to be attributed to an altered condition of the star's hydrogen envelope, or to a diminished absorption in the regions of the lines, cannot yet be determined with certainty. There is, however, some evidence on our spectrograms that the changed appearance of H_β is mostly due to the changed condition of an absorbing atmosphere. The bands in the neighbourhood of H_β [numbered 12, 13, 14 in our tabulations of 1897, *M.N.*, lviii. 348], including the one covering the line, were very strong in 1897, and do not appear on our plates of 1906, but in their stead their sharp edges on the more refractive sides are strong, stout lines. Also the same absorption-bands are weaker, and H_β is stronger on the plates of 1898 than on those of 1897.

The change in the relative intensities of H_γ and H_δ may be accounted for on the same lines, but evidence is wanting on our plates, owing to the weak condition of the absorption-spectrum near H_δ through loss of light in the prism. The objective prism shows a weak absorption-band about H_δ; and if this was, like the rest, stronger in 1897, we should conclude that the change must be attributed to the radiation of the origin rather than to external absorption. The same prism has shown that though apparently weaker than H_γ, H_δ still claims to be the strongest of the series. For on December 1 plates were simultaneously exposed on both spectrographs; and while H_δ appears weaker than H_γ by the compound prism, it is quite its equal by the objective prism, without allowing for the less sensibility of the plate to the H_δ radiation.

Other peculiarities of the hydrogen spectrum have been brought out at this maximum by the objective prism. We have now a photographic record of the series from H_β to H_σ, in which there is no sign of H_ϵ, while H_ζ is quite strong. But the three following lines H_η H_θ H_ι, although they are conspicuous bright lines on the stronger photographs, are out of proportion weaker than H_ζ, their intensities following the natural order of sensibility, decreasing with shorter wave-lengths. The next nine lines are, again, out of proportion weaker than the preceding three. They are extremely

feeble, and are seen only on the strongest photographs, numbered 1983, 1990, and 1992, one of December 12 and two of the following January 3. But they are all easily pointed with a low-power micrometer eyepiece, especially on plate 1992; and they are all bright lines.

The following lines have also been noted as more probably fine bright radiations than thin separations of very broad absorptions, at λ 3843, 3853, 3862, 3872, 3893, 3905.

A special search has been made for the bright lines quoted by Plaskett,* but without any satisfactory result. Our spectra are probably too small. But three lines found at λ 4106, 4119, 4137, agreeing with three of Plaskett's lines, might be called possible bright lines.

But the most remarkable feature brought out by the objective prism is the character of the hydrogen lines. Mr Plaskett, of the Dominion Observatory, has observed on his plates an asymmetrical widening of the lines on the red side, which was more marked on the denser photographs: "No trace could be found of Campbell's triple formation. . . . The lines were, however, in the majority of the plates, unsymmetrically broadened with respect to the actual centre of intensity determined from the tips of the emission lines. . . . . And this asymmetry became more evident the more intense became the line." †

On all our plates by the Thorp objective prism, excepting two of weaker photographic intensity, H^{δ} appears greatly widened on the red side, shading down, but terminating in a comparatively strong bright line; and the same feature is seen in H_{γ} but with less dispersive separation; also on three extra-dense impressions the same is seen in H_{ζ}.

In all cases the features are greatly exaggerated by over-exposure, and there is some evidence of their being more pronounced when the definition is less perfect. On this account, and still more on account of the total absence of apparent asymmetry of the lines on the series of plates by the Hilger compound prism, the writer has long hesitated to put the facts on record. But, after many repeated examinations of both series of photographs, he has come to the conclusion that they cannot be attributed to any photographic freak. And in favour of this conclusion it must be observed, first, that the absence of asymmetry on the photographs by the Hilger prism is quite explained by the great prismatic absorption of the H_{δ} region, and our unfortunate want of a sufficiently over-exposed plate to bring out the weaker extension of the line; while the dispersion at H_{γ} would be too small to be effective. Secondly, that the features cannot be attributed to inferior definition is satisfactorily established by two photographs of December 10, although at first examination these were the plates that threw doubt upon the reality of a stellar origin of the phenomena. On the first of these

* *Spectrum of Mira Ceti*, by J. S. Plaskett, Roy. Astr. Soc. of Canada, Jan.–Feb. 1907.

† *L.c.*, p. 52.

the photographic intensity is very great with poor definition, and the red-side wing terminating in a bright line is seen very clearly in H_γ H_δ and H_ζ. On the second, the impression is weak with perfect definition, and there is little or no sign of the wing even in H_δ; but alongside of this line there is a feeble but quite distinct bright line in precisely the position of the bright line termination of the wing on the preceding plate: the exposure was just enough to bring out the stronger edge of this extension, leaving the weaker interval untouched; and the same condition of things was found on the other excepted plate of December 1. Again, the measured intervals between the strong centres and the bright line terminations of the wings in H_γ H_δ and H_ζ agreed in showing the same spectral interval of 5-tenth metres.

Our photographs therefore go to confirm Campbell's observation of the triple formation of the hydrogen lines, but enormously developed; and the Dominion plates with a prolonged exposure might have provided additional evidence with further details.

1907 *June* 4.

Note on the Visual Spectrum of Mira Ceti in December 1906.
Rev. A. L. Cortie, S.J.

The spectrum of Mira Ceti was examined visually with a Maclean star-spectroscope attached to the Perry Memorial 15-inch equatorial on the evenings of Dec. 6 and Dec. 9. The visual magnitudes of the star on these two dates have been kindly furnished by Colonel E. E. Markwick, from means of observations by members of the variable star section of the British Astronomical Association, as 2·07 mag. on Dec. 6 and 2·00 on Dec. 9. The maximum intensity in the visual spectrum on these dates was unmistakably in the red and the orange part of the spectrum. The most brilliant part of the spectrum was the bright background or band which began sharply at the edge of Duner's second band at approximate λ 6164 and shaded off towards the violet. The red background to the Duner's bands beginning at approximate λ 6493 and 6164 was very brilliant. The bright space between these two absorption-bands had a central maximum of brightness. With regard to the brilliant space beginning at λ 6164, the edge was so sharp and bright and the intensity faded so perceptibly towards the violet that visually it appeared as a bright band. At least it is safe to affirm that the maximum of brightness of the star was in the region λ 6164–5958. In the telescope on Dec. 6 the star was distinctly golden in hue, and was much redder than Aldebaran when compared with that star on Dec. 9. These visual observations of the spectrum are confirmed in all details by four plates taken with the Hilger compound prism on the nights of Dec. 6, 9, 13, and 14. The plates were stained with pinachrom; and although, as was proved by a trial plate taken of α Cygni, the effect of the dye is to give an exaggerated importance to the orange

part of the spectrum, yet the general appearance of the photographic spectrum on a plate dyed with pinachrom approximates more to the visual spectrum, than photographs taken on isochromatic or ordinary plates. The hydrogen bright lines H_γ and H_δ were well seen on Dec. 6. Assuming that the increased brilliancy of the star at maximum is due to temperature, it is important to notice that the extension of the spectrum into the violet is also accompanied by a much greater radiative power in the red and orange part of the spectrum.

Stonyhurst College Observatory:
1907 *June* 6.

Note on the Colours of α and ο (Mira) Ceti.

By W. S. Franks.

In the paper communicated by the Radcliffe observer on the magnitude of ο (*Mira*) Ceti [*Monthly Notices*, April 1907, p. 412] there are some remarks on its colour, as compared with α Ceti and other stars. Perhaps some of my recorded observations of these objects may be of interest, as they cover a period from 1876 to 1893. Briefly they are as follows:—

ο Ceti orange-red, 26 Nov. 1876, 5-inch o.g.
„ splendid yellow, 28 Nov. 1877, „ (near *maximum*).
„ bright yellow, 22 Oct. 1878 „
„ decidedly red, 14 Dec. 1884, $11\frac{1}{4}$ in spec. (about 8^m).
„ orange-yellow, 21 Jan. 1885, „ („ $3\frac{1}{2}^m$).
„ OrR^3 (orange-red), 17 Sept. 1887, $8\frac{1}{2}$ in spec. (est. $7^m \pm$).
„ OrR^2 (pale or. red), 24 Sept. 1887, „ (invis. to n. eye).
„ Or^3 (orange), 4 Oct. 1887, „ (about 6^m).
„ too small for colour, 1892, 3-inch o.g.
„ Y^3 to OrR^3 (10 obs.), 1893, B.A.A. Coloured Star Section.

α Ceti bright orange, 28 Nov. 1877, 5-inch o.g.
„ pale orange, 14 Dec. 1884, $11\frac{1}{4}$ in. spec.
„ Or^2 (pale orange), 24 Sept. 1887, $8\frac{1}{2}$ in. spec.
„ Or^3 (orange), 17 Sept. 1887, $8\frac{1}{2}$ in. spec.
„ Or^3 (orange), 4 Oct. 1887, „
„ Or^2 (pale orange), (5 obs.) 1892, 3-inch o.g.
„ OrY^2 (pale or. yel.), (mean of 33 obs.), 1893, B.A.A. Coloured Star Section.

The colour symbols are those of the nomenclature proposed in vol. xlvii. p. 269 of *Monthly Notices*, which has been found convenient in practice, as by its aid over 36,000 observations have been made, by various persons, of the colours of all the brighter stars in both the Northern and Southern hemispheres, and mean results deduced.

There is no doubt but that *Mira* does exhibit fluctuations in its colour, as evidenced by many observers, but this is probably only an accompaniment of its variation in brightness.

Uxbridge: 1907 *May* 17.

The Relation between Star Colours and Spectra. By W. S. Franks.

During an enforced leisure, I have made some investigations into the connection between the colours of stars and their spectra (see *The System of the Stars*, by Miss Clerke, p. 149), which may possibly be of interest to the Fellows of this Society. The material was gathered from the following sources. For *colours* of the brighter stars, I used the mean values of the observations made by members of the B.A.A. in 1890–3, and published in vol. i. part 3 and vol. ii. part 4 of the *Memoirs* of that Association,—the 928 stars selected depending on about 30,000 observations; they extend from the N. Pole to 25° south declination. For *southern* stars, between −25° and the S. Pole, I made use of the observations by the New South Wales star colour section, published in B.A.A. *Journal*, vol. vi. p. 416 and vol. viii. p. 17. The number of southern stars selected was 432, resting on nearly 5000 observations; the aggregate is therefore 1360 of the brighter stars in both hemispheres. The same colour symbols were used throughout—they are published in the *Monthly Notices*, vol. xlvii. p. 269. The spectra were derived from vol. xxviii. part 2 of the *Harvard Annals* for the southern objects; and for the remainder, from *H.A.*, vol. xlviii. part 4 (catalogue of 1520 bright stars).

At the commencement I made a careful analysis of the colours and spectra of the southern stars, entering all in tabulated form under the 24 headings into which the spectra were divided—a condensed summary of which is seen in Table I. The same was done for the northern stars, as shown in Table II. Table III. is a list of the most obvious *discordances*, which amount to about $2\frac{1}{2}$ per cent. of the whole. Table IV. gives the results of Tables I. and II. combined, and is probably the most trustworthy for generalisation.

TABLE I.

Summary of Analysis of 432 Southern Stars from −25° to S. Pole.

Group.	Division.	Spectra.	Type.	O	YG^1	Y^1	OrY^1	Y^2	OrY^2	Or^2	Y^3	OrY^3	Or^3	OrR^3	R^3	Stars
1	I*a*.	Oa to B9A	Helium stars	46	50	43	6	6	2	...	...	...	...	...	...	153
2	I*b*.	A to A5F	Hydrogen stars	7	9	28	9	13	...	...	...	...	...	...	...	66
3	I.–II.	F to F5G	*a* Carinæ type	1	5	6	6	11	8	...	5	...	...	...	...	42
4	II.	F8G to G5K	Solar stars	...	3	2	5	7	11	...	5	3	2	...	...	38
5	II.–III*a*.	K	Arcturus type	...	...	1	5	4	31	6	6	8	6	...	...	67
6	II.–III*b*.	K2M and K5M	Aldebaran type	...	...	...	...	2	7	1	1	10	20	6	...	47
7	III.	Ma to Md	Betelgeuse type	...	...	...	1	1	3	...	...	2	9	1	2	19
			Total	54	67	80	32	44	62	7	17	23	37	7	2	432

Notes.—Three G^1 included with O; two YG^2 with YG^1; two OrR^2 with Or^2; two OrY^4 with OrY^3; six Or^4 with Or^3; two OrR^4 with OrR^3; and one spectrum Q (Peculiar), η Carinæ, in R^3.

TABLE II.

Summary of Analysis of 928 *Northern Stars, etc., from* −25° *to N. Pole.*

Group.	Division.	Spectra.	Type.	O	YG[1]	Y[1]	OrY[1]	Y[2]	OrY[2]	Or[2]	Y[3]	OrY[3]	Or[3]	OrR[3]	Stars.
1	I*a*.	Oe to B9A	Helium stars	·79	19	26	2	2	1	...	...	...	...	...	129
2	I*b*.	A to A5F	Hydrogen stars	161	71	76	2	1	...	...	...	...	...	...	311
3	I.–II.	F to F5G	*α* Carinæ type	2	6	72	2	12	...	...	1	...	...	...	95
4	II.	F8G to G5K	Solar stars	...	...	24	7	70	18	4	16	2	1	...	142
5	II.–III*a*.	K	Arcturus type	...	...	2	7	82	37	3	41	2	...	...	174
6	II.–III*b*.	K2M and K5M	Aldebaran type	...	...	...	...	2	11	3	6	6	...	...	28
7	III.	Ma to Md	Betelgeuse type	...	...	1	1	1	23	13	4	2	2	2	49
			Total	242	96	201	21	170	90	23	68	12	3	2	928

Notes.—One B[1] and one G[1] included with O; one Or[1] with OrY[1]; and one Y[4] with Y[3]. The spectrum type H in the "Draper" Catalogue (*H.A.*, vol. xxvii.) has been included under G5K, as it does not find a place in the later classification of the southern catalogue (*H.A.*, xxviii. 2).

TABLE III.

List of the Largest Discordances.

a. From Northern List (II.).

Star.	R.A. 1900 h m	Decl. ° ′	Spect.	Col.	Remarks.
κ Cassiop.	0 27·3	+62 23	B	OrY[1]	Possibly *var.* in col.; previous obs. give O and Y[1].
P. III. 54 Cam.	3 21·0	+59 36	B9A	OrY[2]	Certainly *yel.*; confirmed by previous obs.
P. III. 51 ,,	3 21·9	+58 32	B9A	OrY[1]	Possibly *var.* in col.; previous obs. range from Y[1] to Y[3].
μ Persei	4 7·6	+48 9	G	Y[3]	Strong *yel.*; confirmed by previous obs.
29 Can. Maj.	7 14·5	−24 23	Oe	Y[2]	Col. confirmed by previous obs.
ξ Argûs	7 45·1	−24 37	G	Y[3]	Strong *yel.*; confirmed by previous obs.
ρ ,,	8 3·3	−24 1	F5G	Y[3]	My previous obs. make this YG[2]?
ρ Ophiuchi	16 19·6	−23 14	B	Y[2]	Col. confirmed by previous obs.
μ Aquilæ	19 29·2	+ 7 10	A?	Y[2]	Decidedly *yel.*; previous obs. range between Y[2] and Y[3].
β Capri.	20 15·4	−15 6	G comp.	Y[3]	The brighter component of the well-known double; decidedly *yel.*; the companion (A or A2F) appears *blue* by contrast, but in reality it is probably *white*.

TABLE III.—*continued.*

b. From Southern List (I.).

Star.	R.A. 1900. h m	Decl. ° ′	Spect.	Col.	Remarks.
s Eridani	2 36·0	−43 20	A	Y^2	Lines broad and ill-defined (*H.A.*, xxviii. 2).
α Carinæ	6 21·8	52 39	F	O	Col. confirmed by A. S. Williams.
κ Can. Maj.	,, 46·1	32 24	B2A	Y^2	Lines broad and ill-defined (*H.A.* xxviii. 2).
χ Carinæ	7 54·2	52 43	B3A Pec.	OrY^2	Either spectrum or colour wrong?
Lac. 3105 Puppis	,, 55·3	48 58	B1A	Y^1	Spect. binary; fainter component B3A (*H.A.*, xxviii. 2).
d Velorum	8 40·8	42 17	G5K	YG^1	Col. too pale for type of spectrum.
A Centauri	11 30·0	53 42	B8A	OrY^2	Spectrum or colour wrong?
β Hydræ	,, 47·9	33 21	B9A	Y^2	Do. ?
γ Crucis	12 25·6	56 33	Mb	Y^2	But A. S. Williams makes it OrR^3, which agrees with spectrum.
g Centauri	13 43·6	33 58	Mb	OrY^1	Spect. clearly type III.; col. wrong?
υ^1 ,,	,, 52·5	44 19	B3A	Y^2	Spectrum or colour wrong?
θ ,,	14 0·8	35 52	K	Y^1	This type is strongly *yel.*; *maximum* falls in OrY^2.
V ,,	,, 13·3	55 56	B5A	YG^2	Possibly this ought to be YG^1?
μ Lupi	15 11·5	47 31	B8A	Y^2	Spectrum or colour wrong?
γ Circini	,, 15·4	58 58	B5A	Y^2	A. S. Williams makes this O. It is a composite spectrum; the other component F8G or G nearly = mags. (*H.A.*, xxviii. 2). Possibly spect. binary, with colour changes?
k Lupi	,, 18·8	38 22	A	Y^2	Spectrum or colour wrong?
η Normæ	,, 55·8	48 57	G5K	YG^1	Do. ?
ϵ ,,	16 19·8	47 20	B5A	Y^2	Composite spect., other component type I. (*H.A.*, xxviii. 2).
τ Scorpii	,, 29·7	28 0	B	Y^1	Tupman, Gage, and Baracchi make it O, which is probably correct.
θ Aræ	17 58·8	50 6	B1A	YG^2	Possibly should be YG^1?
γ Pisc. Aust.	22 47·0	33 24	A	Y^2	Spectrum or colour wrong?

TABLE IV.

Summary of Analysis of 1360 *bright Stars.*

(*Combined Results.*)

Group.	Division.	Spectra.	Type.	O	YG^1	Y^1	OrY^1	Y^2	OrY^2	Or^2	Y^3	OrY^3	Or$^{3'}$	OrR^3	R^3	Stars.
1	I*a*.	Oa to B9A	Helium stars	125	69	69	8	8	3	...	...	...	..	...	...	282
2	I*b*.	A ,, A5F	Hydrogen stars	168	80	104	11	14	...	...	...	...	...	...	...	377
3	I.–II.	F ,, F5G	*α* Carinæ type	3	11	78	8	23	8	...	6	...	...	...	...	137
4	II.	F8G ,, G5K	Solar stars	...	3	26	12	77	29	4	21	5	3	...	...	180
5	II.–III*a*.	K	Arcturus type	...	...	3	12	86	68	9	47	10	6	...	...	241
6	II.–III*b*.	K2M and K5M	Aldebaran type	...	...	...	...	4	18	4	7	16	20	6	...	75
7	III.	Ma to Md	Betelgeuse type	...	...	1	2	2	26	13	4	4	11	3	2	68
			Total	296	163	281	53	214	152	30	85	35	40	9	2	1360

Grouping together O, YG^1, Y^1, and OrY^1—the last 3 being *white* with the faintest perceptible tinge of colour; Y^2, OrY^2, and Or^2 as *pale* tints; Y^3, OrY^3, and Or^3 as full or *normal* tints; OrR^3 and R^3 as *ruddy* tints; we have—

White, or nearly white, stars	793 :	p. cent.	58·3 :	55·2	(Fr's obs. 1884–6).
Pale tints, yel. to orange ,,	396 :	,,	29·1 :	35·2	,, ,,
Full ,, ,, ,,	160 :	,,	11·8 :	9·6	,, ,,
Ruddy tints, orange-red and red stars, ...	11 :	,,	·8 :	·0	,, ,,
	1360		100·0	100·0	

The last column gives the percentage results I found in 1884–6 from 1744 stars, and it is interesting to note the comparison.

It will be seen that the proportion of colourless stars is similar in groups 1 and 2, the *maximum* for both series being in O (white). In group 3 the typical tint is Y^1 (yellowish-white); in group 4 it is Y^2 (pale yellow); and in group 5 it lies between Y^2, OrY^2 (pale orange-yellow), and Y^3 (normal yellow). The reason for making a subdivision in II.–III. was that there were *two maxima*—the other falling in OrY^2, OrY^3 (normal orange-yellow), and Or^3 (normal orange) = group 6. The last group is very similar to 6 in colour distribution, and it would be difficult to tell merely by eye observation of colour to which of these groups a star belonged, although the spectra are essentially different. On the whole, there is undoubtedly a striking agreement between the colours and spectra of stars; but as the spectral types shade off almost imperceptibly into each other (though in a rational sequence), so likewise do the tints of the stars. It is this overlapping which is responsible for most of the apparent departures from the normal; and we must also remember that the tints of two stars may be apparently similar even with a different arrangement of lines (see *Problems in Astrophysics*, by Miss Clerke, p. 263), whilst two stars of similar spectra may differ perceptibly in tint.

In connection with this subject it may be mentioned that there is a curious affinity between Helium stars (B type) and *bright* line spectra (O type), with the *Galaxy*. Some of the latter type are associated, too, with *nebulæ*, as 15 (S) Monocerotis, ι and θ Orionis, and η Carinæ (which also has a bright line spectrum, though very peculiar). *All* the bright line spectra met with in this investigation were in or near the Milky Way; and this becomes still more remarkable when we remember that *all* the "Wolf-Rayet" stars (some 70 in number), *all* the temporary stars (novæ), and the majority of short-period variables are also found in this region. The Galaxy seems to be the plane of origin of some of the most striking phenomena in the stellar universe; and such association cannot be merely accidental, but must be the result of some grand physical law, at present undiscovered.

Uxbridge: 1907 *May* 24.

On the "Owl" Nebula, Messier 97 = N.G.C. 3587. 1860.0.
$\alpha = 11^h\,6^m\,40^s$. $\delta = +55^\circ\,46'.7$. By E. E. Barnard. (Plate 3.)

There has always been much interest attached to the great reflecting telescope of Lord Rosse. This giant instrument was used mostly in the study of the nebulæ, for which its great light-grasping power made it singularly useful. All the well-known nebulæ were studied with it, and drawings or sketches were made of many of them. There is little known as to the performance of the instrument on objects where definition was specially required. A comparison with the large modern refractors can only be had, therefore, through the agency of the nebulæ. Such a comparison must be crude at best from the difference in climate, observers, etc. Nevertheless, it would seem possible to form some idea of the power of the telescope in dealing with the nebulæ by a comparison of the drawings and descriptions with the present appearance of these objects as seen in the actual sky. To compare these drawings with photographs of the nebulæ would be very unfair, because of the extraordinary power of the sensitive plate compared with that of the eye when dealing with such objects.

A visual comparison of this kind would be well worth while, and might lead to important information concerning probable changes in the nebulæ, though there seems to be but little hope of anything in this direction except through the aid of photography at very long intervals of time.

The relative amount of light collected by the 40-inch refractor of the Yerkes Observatory and the 6-foot Rosse reflector would be 1 : 32 for a point source. If the relative effectiveness were the same, the 6-foot should have shown an object 32 times fainter than could be seen with the 40-inch telescope. Inasmuch as the great speculum was of metal, there must have been a serious loss of light to begin with. The power of the instrument must also have varied greatly according to the condition of the surface of the speculum, for Lord Rosse stated that it was subject to considerable tarnish because of the necessary amount of copper in the material.

I have examined, both with the 36-inch of the Lick Observatory and the 40-inch here, a large number of the nebulæ—especially of the planetary nebulæ—which were drawn by Lord Rosse and his assistants. From their observations, I believe, on the whole, that the 40-inch telescope will show anything that could have been seen with the great reflector, even where light alone is concerned. True, there are some details of the nebulæ in the Rosse drawings that are not visible in the 40-inch. At the same time there are others that the great reflector failed to see which are visible in the 40-inch. There is little to be said on this point, therefore, without prejudice.

Very often the Rosse drawings show fringes around the planetary nebulæ, or "beards," that are not seen in the 40-inch. I do not know that these are verified by photographs. One is almost

tempted to ask if this singular feature was not in some way a product of the great reflector itself—a want of exact definition. I offer this only as a possible explanation, which in itself seems to me to be very doubtful. Instances of this peculiarity are seen in the drawings of M 97, M 57, G.C. 450, G.C. 2098, G.C. 464, etc. But these appendages do not seem to be real.

A remarkable example of some of these peculiarities is the drawing of M 97—the celebrated "Owl" Nebula—made in 1848 with the great reflector. This picture for a half century was a classic among the drawings of nebulæ. And indeed it might well be, for it represented the nebula as a weird bewhiskered grinning face, with two dark spots where the eyes should be. In each of these dark spots or eyes a considerable star, which formed the pupil of the eye, was shown. The whole representation is strikingly like the face of an owl, or some uncanny cross-eyed goblin which only needs a pair of legs to execute some fiendish dance in space.

In recent years this fascinating picture seems to have dropped out of astronomical books, mainly, I believe, because when the nebula was examined in the sky with other powerful telescopes the two stars no longer formed the pupils of the eyes. In fact, there seemed after all to be only one star in the nebula; and this star, furthermore, was not in either of the eyes, but really occupied the bridge of the nose between the eyes!

Nevertheless, I believe that this drawing, shorn of some of its structural details and appendages, is important. There does not seem to be any question but that there were two stars in the nebula which were seen with the great telescope in 1848 and later. The main question is the true location of these two stars at that time with respect to the large dark spots in the nebula. If the drawing, which seems to be corroborated by the observer's notes, correctly represents the position of these two stars—both or either one—as being in the dark spots, then a change has occurred in the nebula, for the two stars are there and have not changed their places in the sky.

The brighter of these two stars occupies the centre of the nebula. In the observations of 1848 it is described as being in the centre. If this star is the nucleus of the nebula—and it probably is, though it is more star-like in appearance than are the nuclei of the nebulæ in general—then the nebula has not moved, for the star has not sensibly changed its place.

There is only one other means by which a displacement of the holes with respect to the two stars is possible, and that is a rotation of the nebula. Motion of translation or of rotation in the nebulæ is not improbable when time enough lapses to show it. We do not have, however, a single example where motion is proved, outside of spectroscopic results.

If this nebula were sensibly rotating from west to east, on an axis whose position angle is 50°, then the holes would have been further east on the disc in 1848; and if the velocity of rotation

were great enough, the two stars would have occupied the position in the holes shown in the drawing of Lord Rosse. While I do not believe this is the true explanation of the discrepancy in the early drawings of this nebula, it will at least serve as a working hypothesis.

Following is a collection of notes which relate to the stars in the nebula. They are taken from the papers of Lord Rosse in the *Philosophical Transactions of the Royal Society* and the *Scientific Transactions of the Royal Dublin Society.*

From the *Transactions of the Royal Society*, 1850.

1848 March 11. Two stars considerably apart in the central region. Dark penumbra around each, spiral arrangement, with stars as apparent centres of attraction; stars sparkling in it, resolvable; night excellent. Note by Mr Rambaut.

1848 March 11. Remarkably fine night; a brilliant star in the centre; also star to the right; round each a black space (see sketch). Note by Mr Rambaut.

1848 March 26. Second bright star visible; spiral arrangement hardly perceptible; not seen so well as on the 11th of March.

1848 March 27. Not seen so well as last night; second star seen at rare intervals, power 468.

1848 March 28. Night hazy, could not see second star.

1848 March 31. Caught one glimpse of second star, but saw the large star very plainly.

1848 April 3. Small star distinctly seen.

1848 April 6. First star seen easily, though hazy; the second only occasionally.

1848 March 9. Second star only seen for a moment. Several attempts were made to procure measures of position and distance of the two stars this spring, but in vain, the season was so unfavourable. . . . With the micrometer as at present mounted there would not have been the slightest difficulty in procuring measures.

From the *Transactions of the Royal Dublin Society*, vol. ii. (New Series), Aug. 1879.

[See p. 7, 1850. Plate xxxvii. fig. 11.]

1848 March 11. Brilliant star in the centre. After 5^m observation detected the star to the right, which Dr Robinson immediately saw. Round each star seems a black space.

1848 March 26. Seen better than last night. 2nd star seen at frequent intervals with S star appearing now and then through the neb. part.

1848 March 27, 28, 31, April 1. Not well seen, 2nd star only seen at rare intervals.

1848 April 3. S star seen plainly enough.

1850 March 9. S star barely visible for a moment. Uncertain measure of its pos. from central star 331°·5 (Lord R.).

Between 1850 March 15 and 1858 March 8, viewed 18 times. S star not seen, nor minute details.

1858 March 11. *v*F star once suspected almost p the central star, but very uncertain. 2nd star not seen.

1858 April 3. Suspected star (see last obs.) not verified. A very minute star s f the middle one, just on the outer edge of dark hole, was more strongly suspected.

1863 Feb. 12. One star plainly seen, and at moments I fancied I saw a star n f it and one in s f edge, but only by glimpses. I have the merest suspicion of one in n p edge.

1868 Feb. 15. Star in centre, one on cross-bar near n extremity, susp. comp. to central star. S star on s f edge of f hole and sev. others susp. at moments.

1868 Feb. 28. Comp. susp. p central star.

1872 March 12. Star n f from central star. Pos. 22°·9 (3). Dist. 157″·6 (3). No other star distinctly seen. power 414, possibly one or two e F st f the central one, on the edge of the hole.

1874 March 9. Minor Axis Pos. 41°·4 (2) Diam. 147″·4 (2).
Major Axis „ 126·2 (2) „ 163·5 (2).
Central star 14 mag., no other st steadily seen.

As will be seen, the notes in these observations are frequently rather vague. Sometimes it is impossible to tell just what is meant.

It seems quite clear, however, that the "second star" frequently referred to was really the one which I have measured and called 2. The note of 1848 March 26, where it is referred to as "second bright star," is not reconcilable with their later observations of it, nor with its appearance to-day, for in the later notes it seems to have been a difficult object.

The direction of the 2nd star given by Lord Rosse on 1850 March 9 of 331°·5 must be 180° in error to agree with the previous descriptions. If this is so, and I think there is no doubt that it is, then the position angle 151°·5 would agree as closely as could be expected with my observation of 153°.

On 1907 April 5 I gave an exposure of 6^h 0^m on the place of this nebula with the Bruce 10-inch doublet. The sky was fair for such work, but not specially good. Clouds at one time covered the region.

The general appearance of the nebula on this photograph is that of a round mass, with a bright central star and two unequal dark places, one on each side of this star. The following is a description of the object under a considerable magnifying power as it appears on this plate. There seems to be a slightly elliptical disc, with its axis very roughly in P.A. 160°, superposed unsymmetrically upon a fainter circular disc. The greatest displacement of these two discs is on the following side, where the edge of the brighter one is $\frac{2}{10}$ of radius nearer the central star. There is some detail in the south preceding portion of the nebula in the form of a narrow curved mass of greater

brightness running toward the south side. There is also some detail of a similar nature near the north edge. The following hole is much smaller than the preceding one, its following edge is not quite $\frac{1}{2}$ radius from the nucleus. The preceding edge of the preceding hole extends over $\frac{7}{10}$ radius from the nucleus. The nucleus is so large that it almost obliterates the separation between the two holes, so that they appear nearly to merge into each other. There are suggestions of considerable detail on the nebula—especially in the north and south parts. The second star (2) is faintly visible just outside the south following edge of the following hole. There are no traces of fringes or other appendages to the nebula.

Among the many nebulæ photographed by the late Dr Roberts with his 20-inch reflector was M 97. A reproduction of his photograph is given in vol. ii. of Roberts' Celestial Photographs. Of this photograph which was made on 1895 April 20 with four hours' exposure, Dr Roberts says: "It (the nebula) measured about 203″ of arc in length, and the star referred to by Rosse is very conspicuously seen in the centre, its magnitude being about the 15th, but there is no other star anywhere in the nebula."

Dr Roberts' photograph is wrongly oriented in plate 19. South is above, and following is to the left. Below it, on the same plate, is a photograph of M 57 Lyrae, which is correctly oriented—south above, and preceding to the left. I call attention to this fact, otherwise it may cause confusion in comparing the picture of M 97 with observations. The photograph must be looked at in a mirror, which will correct the orientation. There is no faint star in the open sky outside the nebula on Roberts' plate that is not shown equally well or better on mine.

Following is a collection of my notes on the nebula as it appears with the 40-inch refractor.

1899 Feb. 6. The star (2) is just free of the dark opening. A sketch shows it outside the south following edge of the following hole.

Feb. 7. Small star difficult to measure.

1900 Dec. 18. The small star is not in the south following opening, but is just free of it, and is on the nebulosity south following. This star is rather hard to measure. Sketch.

Dec. 25. A sketch shows the small star just free of the following part of the hole. Very faint and difficult, and only seen by glimpses.

1902 Feb. 7. The central star is $16^{m}\cdot5$. It is very difficult. Can see the other star (2) faintly. The star measured (1) is between the two eyes on the bridge of the nose, but nearer the following hole.

1907 March 5. The edge of the nebula reaches just half way to the 10^{m} star north [star (4)].

March 10. Star 2 is $1\frac{1}{2}$ magnitude less than the central star. The following hole is the more distinct and darker of the two. The central star is nearer the following hole but not in it.

March 17. The central star would be 13^{m} if free from the

nebulosity. Can feebly see the two other stars. The following one (2) is on the south following edge of the following hole. It seems to be either on the edge or within the nebulosity outside the hole. The other small star (3) is very difficult. The preceding hole is further from the centre than the following hole, and there is not much contrast with the nebulosity. That side of the nebula seems somewhat less bright and less distinct. Cannot make out any spiral arrangement. Tried pulling out the eyepiece, but this did not seem to make any improvement. The edges of the nebula, though rather definite, are very indistinct—especially the preceding edge. With a magnifying power of 700 diameters, the south following star (2) is very close to the following edge of the following hole, but outside of the hole. The central star is north following the line between the two holes, and is nearer the following hole. The following hole is the more distinct of the two and is nearer the middle.

April 2. Sky fairly clear. The following estimates of brightness were made. Central star (1) = $13\frac{1}{2}^{m}$ or 14^{m}. Star (2) = 15^{m}. Star (3) is 1 magnitude less bright than (2). Tried drawing out eyepiece, but could not see any more details. There does not seem to be any structure, spiral or otherwise. The nebula is irregularly round—the edges very ill-defined.

I have the following observation of this object with the 36-inch, 1894 April 8, with a magnifying power of 350. There is a rough sketch of the central star and the two holes :—

"The nebula is round. The edges fairly well terminated. There is a 15^{m} star [the central star] just free of the preceding edge of the following dark hole ; there are one or two faint stars south following this hole, but no star in either hole. The following hole is the more noticeable. I do not see any spiral structure. The [central] star is on the following side of the bridge, but not in the hole."

I suppose the "one or two faint stars south following the hole" were stars (2) and (3). The description of the position of the central star on the bridge between the two dark holes would rather show there has been no decided change in the holes in the past ten or fifteen years.

I think the central star is variable. It has sometimes appeared much fainter than at others. Of course it is very difficult to decide on the variability of a faint star involved in nebulosity, for conditions of seeing, etc. affect it far more than when the star is in the open sky. On 1902 Feb. 7 it was estimated to be $16\frac{1}{2}$ magnitude, and was very difficult. I would not consider this alone as of any importance were it not that a note says that star (2) was visible. This would imply that there could be but little difference in their brightness at that time. It will be watched further for change.

Below are given my measures of the stars in this nebula. The diagram on Plate 3 shows the relative places of these stars with reference to the two dark spots.

Measures of Stars in Messier 97.

Nucleus (1) and (4).

			m	m	
1899 Feb. 6	24°·85	157″·52	14	10	
7	.....	158·58			Single distances.
	24·85	158·05			
1900 Dec. 18	24·86	158·28	13	10	
25	24·92	157·90		10·5	
28	24·70	157·99	14	10·5	
	24·83	158·06			
1902 Feb. 7	24·80	157·69	16·5	10	
8	24·97	158·26			
24	24·98	158·68			
	24·92	157·88*			
1907 Feb. 10	24·72	158·06			
Mar. 5	24·94	158·01			
	24·83	158·03			

Nucleus (1) and (5).

			m	
1900 Dec. 25	184°·77	180″·87	12	
28	184·88	181·20	12	
1901 Jan. 20	184·91	181·13	11·5	
	184·85	181·11*		

Nucleus (1) and (2).

			m	
1900 Dec. 25	152°·89	40″·76	16	
1907 Mar. 10	153·99	40·78	16	
	153·44	40·77		

Nucleus (1) and (3).

			m	
1907 Mar. 5	205°·1	36″·8	16	Single distances.

In volume ii., Publications of the Lick Observatory, Professor Burnham gives three measures of the central star and the 10 magnitude star north. The mean is :

			m	m
1891·24	24°·8	156″·48	14·2	10·5

* At the moment of going to press it was noticed that these means are not consistent with the figures above. The necessary rectification will be made in the next Number.

He does not mention any other stars in the nebula.

From the visual observations in March of the present year, the following facts were determined:—

Diameter of the following hole = 34″·0 (1).

Diameter of the nebula in the direction of 25° = 155″·4 (1).

Distance from following edge of following hole along the axis of the two holes to following edge of nebula = 43″·4 (1). Position angle of the line between the centres of the two holes = 134°·2 (2). This line would pass 5″ or 10″ south preceding the central star.

To decide whether the "central star" was really central in the nebula, the distances from the star to the edges of the nebula in four directions were measured:—

P.A.	28°	81″·0	(2)
	118	81·6	(3)
	208	80·3	(2)
	298	80·0	(4)

It was difficult to set on the edges of the nebula, especially in the direction 28°. In that direction another night's measures gave 71″·2 (2), but the seeing was very bad, and the photograph shows that the fainter outline here was perhaps not seen, and that the measures doubtless refer to the edge of the brighter disc. I have rejected that set. The central star would therefore appear to be in the centre at least of the fainter disc. A mean of all the measures would make the diameter about 160″. The numbers in parenthesis indicate the number of settings of the wires.

A copy of my drawing of M 97 is given in Plate 3. It is a fair representation of the nebula as it appears in the 40-inch telescope. For comparison, I have mounted beside it a copy of the Rosse drawing, which I have assumed is correctly oriented in the *Philosophical Transactions* for 1850, south above, preceding to left. I have, however, tilted it so that the line between the eyes is parallel to that in my drawing. The Rosse picture is more interesting when turned upside down.

Yerkes Observatory:
1907 *May* 16.

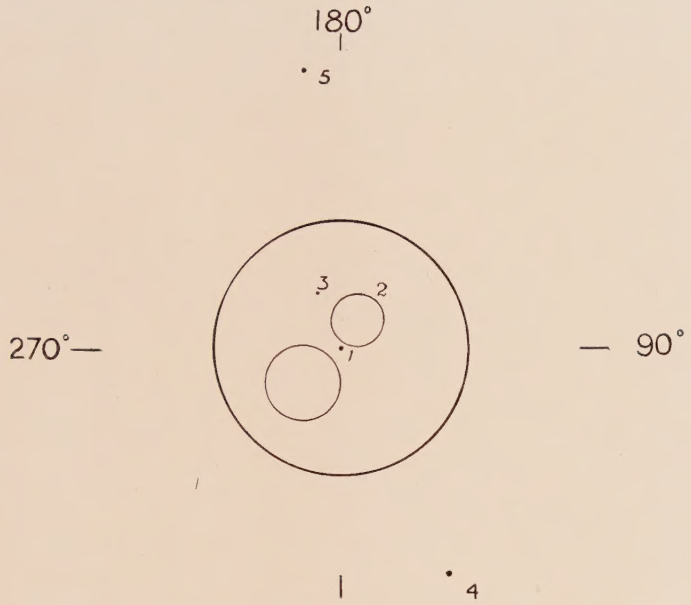


DIAGRAM OF THE "OWL" NEBULA FROM THE MEASURES.

SOUTH.

THE "OWL" NEBULA WITH LORD ROSSE'S GREAT REFLECTOR IN MARCH OF 1848.

THE "OWL" NEBULA WITH THE 40-IN. REFRACTOR OF THE YERKES OBSERVATORY IN MARCH 1907